

T H E
M O T I O N
O F
F L U I D S,

NATURAL and ARTIFICIAL;

See

In particular that of the

Crutch

A I R and W A T E R:

I N A

Familiar Manner proposed and proved
by evident and conclusive EXPERIMENTS,
to which are added many useful REMARKS.

D O N E W I T H

Such PLAINNESS and PERSPICUITY, that they
may be understood by the UNLEARNED.

For whose Sake is annexed,

A Short EXPLANATION of such Uncommon Terms,
which in Treating on this Subject could not, without
Affectation, be avoided.

W I T H

Plain DRAUGHTS of such EXPERIMENTS and MACHINES,
which, by Description only, might not readily be comprehended.

Nata est Ars ab Experimento. QUINTIL.

By M. CLARE, A.M. & F.R.S.

The THIRD EDITION, Corrected and Improved.

L O N D O N,

Printed for A. WARD, J. and P. KNAPTON, S. BIRT, C. HITCH,
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J. RIVINGTON. 1747.





To the Right Honourable
HENRY, ARTHUR,
LORD HERBERT,
Baron of *Chirbury*, &c. &c. &c.

MY LORD,

WE have been told by Writers, fond of drawing the most discrediting Pictures of Human Nature, that the

DEDICATION.

Love of our Country, is an imaginary Virtue, rather existing in the pompous Descriptions of Poets and Orators, than in the real Occurrences of Life.

THIS Assertion can be nothing less than a flagrant Violation of Truth and Decency : Since the *British* People have lately given very illustrious Proof of their publick Spirit, in the Suppression of an unnatural Rebellion ; and in unanimously agreeing to shew as bright a Specimen of their Gratitude, by distinguishing Your LORDSHIP, for your Part therein, with the venerable Appellation of a *British* Patriot.

OUR

DEDICATION.

OUR Countrymen, MY LORD, in Despite of the Malignity of Faction, generally think, that publick Fame is due to publick Services : But have seldom paid the Complement of their Esteem, with greater Propriety, than when they saw Your LORDSHIP, exerting the Spirit of Patriotism, in its utmost Strength ; animating Multitudes with the Warmth of national Affection, and supporting the Cause of Liberty, from such Motives, as raise Men into Heroes.

IF there be in this Kingdom, a Stranger to Your LORDSHIP's private Character, he will conclude

DEDICATION.

clude it must be Great and Noble, from the Activity of your Zeal, in raising a Regiment, at your own Expence, from among your Friends and Dependents, in Defence of our legal Government, and our civil and religious, most valuable, Rights : For an affectionate Attention to the true Interests of Society, the invariable Rule of Your LORDSHIP's Conduct, has so strict a Connexion with the whole System of human Virtues, that none of them, in the Composition of so worthy a Patriot, as is Your LORDSHIP, can be wanting.

At the same Time that I present You the *Third Edition* of

DEDICATION.

of my little Work, I claim the
Protection of an antient Friend-
ship, for giving You this publick
Testimony of the Veneration,
wherewith I am,

Your LORDSHIP's

most Obedient,

and most Obliged,

Humble Servant,

Soho-Square,
Dec. 30, 1746.

Martin Clare.



ADVERTISEMENT.

THE following Sheets are the Substance of some Lectures, privately read to a Set of Gentlemen, who were so indulgent, both to the Matter and Form, as to encourage their Publication, for the Use and Advantage of Those who may have wanted Opportunities of inquiring into such Natural Causes as are the Subject-Matter of them; viz,

I. HYDROSTATICKS, whereby the Nature of the grosser Fluids is explained; their Motions on the Principle of Gravity ascertained; most of the Varieties of which Motions, whether in Pipes, Pumps, Syphons, Fire-Engines, Jets-d'Eau, or the chief Water-Works in Use, are both delineated to the Eye, and demonstrated to the Understanding,
in

Advertisement.

in so familiar a Way, that 'tis hoped even the Unlearned may, without great Difficulty, comprehend them. To which is added the concise Way of discovering the Specific Gravity of Bodies, by weighing them in Water.

II. PNEUMATICKS, wherein the chief Properties of the Air, its Pressure and Spring, are made appear by Experiments and undeniable Proofs. Under which Head, short but clear Sketches of Muscular Motion, the Circulation of the Blood, the Process of Digestion and Nutrition, with several other curious Subjects relating to the Animal Oeconomy, so far as they are at present understood, are occasionally introduced. The Meteorology, or the Cause and Origin of the Winds, Clouds and Storms, generated in the Regions of the Air, with the Cause and Progression of Sounds conveyed to the Ear by Means thereof, are also endeavoured to be illustrated from Reason, or are proposed from the best Authorities. The Instruments

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ments also for observing the Alterations in the State of the Air, are herein particularly described, and the Art of Diving fully explained.

I N doing whereof, Care has been taken to be as succinct as was consistent with Perspicuity, and to use as few hard Words as possible : Such uncommon Terms however as could not be well avoided in treating on these Subjects, are by the short Glossary at the End of the Treatise, sufficiently explained.

I F these Sheets do not contain any new or notable Discoveries in either of the Branches of Science proposed, 'tis hoped, that what has been found out relating to them, will appear to be so well connected, and disposed in so clear a Light, that the Reader may therein find at least Matter of Amusement ; and, by perusing them, may not only become a tolerable Judge of what may be done in this Way, but be also made acquainted with the Manner of performing it.
The

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The Artist will probably receive some Benefit from having the Reason and Principles of many Things he daily sees and does, explained to him in an easy and familiar Manner. The young Philosopher may certainly be assisted hereby in his first Searches after Truth: Besides which Advantage, his Mind will be better prepared for receiving Lectures in Natural and Experimental Philosophy; which might easily be introduced into most Regular Societies, and so become of singular Use and Benefit to Mankind. That which by Experiment is made the Object of our Senses, is generally found to leave deeper Impressions on the Mind, than Instruction in any other Way.

THE Advantage Things of this sort are already of to the World, appears in the frequent Improvements now made in all those Things which either serve the Interests, supply the Necessities, or farther the Convenience of Mankind. By Experiments performed with Accuracy and Judgment, 'tis certain

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tain Arts and Sciences have been more advanced within the last Century, than in several Ages before. The Hypotheses, or rather Philosophical Romances of Antiquity being now exploded, our Inquiries into Natural Causes are no longer bias'd by conjectural Schemes and the Productions of warm and pregnant Imaginations; but our Principles are built on the surest and most rational Basis, that of Experiment and Fact; which cannot but be always acceptable to those who admire Demonstration, and delight in Truth.

Nullius in Verba : ——— Experimentis
ducor ad consentiendum.

Symbol. Reg. Soc.



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HYDRO



HYDROSTATICKS:

OR,

The Motion of FLUIDS,

NATURAL and ARTIFICIAL.

STATICKS in general shew the Equipoize of Bodies, and their Difference in point of Weight; and mere Staticks make up a Science only speculative.

HYDROSTATICKS is that Part of Staticks, restrain'd to the Weight and Equilibria of Liquid Bodies. Under this Head, not only Accounts of the Nature and Properties of Fluids in general are introduced, and the Laws by which they act; but also the Art of weighing solid Bodies in Fluids, in order to discover their specifick Gravities.

HYDROSTATICKS, as Mr. BOYLE observes, is a Branch of Natural Philosophy inferior to none:

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He terms it a Science resulting from Reason, and affording Discoveries no less pleasing than wonderful ; since neither the most abstruse, or the most familiar Appearances of Nature can be well understood or accounted for, without hydrostatical Principles. He recommends it as an Art, not only delightful in Speculation, but useful in Practice ; of the highest Importance to the Improvements in Trade and Navigation ; necessary to such whose Business it is to compare the Magnitude and Gravities of certain Bodies, as Metals, Ores, &c. and with regard to the Raising of Water, for the Uses of Life, its Importance is beyond Expression.

ON FLUIDITY.

Sir *Isaac Newton's* Definition of a Fluid is, *That it is a Body yielding to any Force impress'd, and which bath its Parts very easily mov'd one among another.*

IT must here be remark'd, That this Definition supposes the Motion spoken of, produced by a partial Pressure ; for in the Case of an incompressible Fluid, it is demonstrated by Dr. KEIL, that under a total or an equal Pressure, 'twould be impossible the yielding Body should move.

THE original and constituent Parts of Fluids are by the Moderns conceived to be, Particles
small

small, smooth, hard, and spherical: According to which Opinion, every Particle is of itself a solid, or a fixed Body; and when consider'd singly, is no Fluid, but becomes so only by being join'd with other Particles of the same kind.

'Tis probable that the Particles of Fluids are exceeding small, because their Texture has never yet been discover'd by the finest Microscope; we judge them to be smooth, because they are found easily to glide one over another; hard and impenetrable, because no Fluid we are acquainted with, the Air excepted, is capable of Compression; we conceive them to be spherical, that they may only touch in some Points of their Surfaces; and so not only may be the more easily mov'd, but also form Interstices or Vacancies between them, which may be proved.

WERE Fluids not compounded of primary Particles, form'd as above, but made up of one uniform homogeneous Substance, without Consistence, equally dense; there would be no Difference in their specifick Gravity, and all Fluids would be of the same Weight, Bulk for Bulk; which is contrary to Experience.

THAT Fluids have Vacuities, will appear upon mixing Salt with Water, a certain Quantity whereof will be dissolv'd, and thereby imbib'd, without enlarging the Dimensions. A Fluid's becoming more buoyant, is a certain Proof that its specifick Gravity is increas'd, and of consequence, that many of its Vacuities are thereby fill'd;

after which it may still receive a certain Quantity of other dissoluble Bodies, the Particles whereof are adapted to the Vacancies remaining, without adding any thing to its Bulk, though the absolute Weight of the whole Fluid be thereby encreas'd.

THIS might be demonstrated, by weighing a Phial of Rain-water critically, with a nice Balance: Pour this Water into a Cup, and add Salt to it: Refund of the clear Liquor, what will again fill the Phial; an Increase of Weight will be found under the same Dimensions, from a Repletion, as has been said, of the Vacuities of the fresh Water with saline Particles.

AND as Fluids have Vacuities, or are not perfectly dense; tis also probable, that they are compounded of small Spheres of different Diameters, whose Interstices may be successively fill'd with apt Materials for that Purpose: And the smaller these Interstices are, the greater will the Gravity of the Fluid always be.

FOR instance: Suppose a Barrel be fill'd with Bullets in the most compact Manner, a great many Small-shot may afterwards be placed in the Interstices of those Balls; the Vacuities of the Shot may then be replenish'd with a certain Quantity of Sea-sand; the Interstices of the Grains of the Sand may again be fill'd with Water; and thus may the Weight of the Barrel be greatly augmented, without encreasing the general Quantity: Now this being

true

true with regard to Solids, is applicable also to Fluids. For instance : River-water will dissolve a certain Quantity of Salt ; after which it will receive a certain Quantity of Sugar ; and after that, a certain Quantity of Allom, and perhaps other dissoluble Bodies, and not increase its first Dimensions.

WAS all Space, as the *Cartesians* affirm, absolutely full of Matter, this Matter must either be fluid or fix'd. Was it fix'd, there could possibly be no Motion therein, as is plain both from Reason and Experience ; it must therefore be fluid. But a Fluid without Vacuities will be denser, consequently heavier, than all Fluids ; and if denser, all Bodies will emerge, and swim therein, by hydrostatical Laws, nor could there be such a Thing as Gravity. But as Gravity cannot be denied, all Space therefore cannot be fill'd, even with a Fluid.

THESE Gentlemen have two Evasions to avoid the Resistance of their Vortices, or Whirlpools of *Subtle Matter* ; by the Motion whereof, they endeavour to account for the known Phenomena or Appearances in Nature. Their imagin'd *Materia Subtilis* they assert to be a perfect Fluid, not incumber'd with the least Clamminess, Cohesion or Tenacity, and therefore capable of no Resistance. To this we reply, that the Resistance of the common Fluids (as Sir ISAAC NEWTON's Experiments after-mention'd, of Bodies falling in different Mediums, shew) arises from the Inactivity of Matter only, proportion'd

6 *The Motion of* FLUIDS,

always to its Density, and not at all from the Cohesion or Tenacity. Take these therefore from the *Cartesian* Fluid, the Inactivity, or *Vis Inertiae*, by no means to be suspended or diverted, will remain in Matter ; it cannot therefore be without Resistance. And as *Mercury*, near fourteen times denser than Water, and Water about eight hundred and fifty times denser than Air, are experimentally found to make proportionable Degrees of Resistance ; the Fluid just mention'd, being much denser than these, will no doubt proportionably resist.

THEIR second Assertion is, That their Fluid does not consist of gross Particles, as others do ; and since, say they, the Diminution of the Particles of Matter lessens the Resistance proportionably, it follows, that their Fluid consisting of Parts infinitely small, can have no Resistance at all. To this we answer ; That though the Diminution of Parts does lessen the Resistance of any single Part, yet is the Resistance of the whole not alter'd : For if a Body be divided into twenty Parts, which, when combin'd, will make a certain Degree of Resistance ; if these be subdivided into twenty more, the Number of Parts will indeed be doubled, each of which will make but a fortieth Part of the Resistance of the whole ; but taken collectively, they will have the same Resistance, and be of the same Weight, as was the Body undivided. Nor is an Ounce of Gold a whit the less ponderous, for being reduced into Dust.

ANO-

ANOTHER Mistake these Gentlemen make, is in their Definition of a Fluid, which they take to be a Body in continual Motion: Urging in Support thereof, that all Bodies have a Tendency to Consistency or Fixation; but that Fluids, by the Motion of their Parts, are kept separate: And to this Motion they attribute their making less Resistance than fix'd Bodies.

IN Answer to which, it may be doubted whether all Fluids have a Tendency to be consistent. Metals indeed, Wax, Butter, and Bodies of like Texture, artificial Fluids only, which are by Fire brought into a State of Fusion, and are to be continued flux'd by a certain Degree of Heat, have a Tendency to be consistent, from the particular Disposition of their Parts: But there may be natural Fluids, such as Mercury, for instance, or Air, which have no such Property.

AND as to the Resistance of Fluids being the less, on account of the continual Motion of their Parts, it ought to be consider'd, that a Body in Motion will not resist less than a Body at Rest. For, suppose a Body moving in a Fluid: Those Parts of the Fluid, which move the same Way with the Body, will indeed give less Resistance; but then those moving in a contrary Direction, will resist the more. And to imagine that an equal Number of Parts can constantly keep moving this way, and an equal Number that, is both ridiculous and absurd. Besides, should it be granted, that the Particles of a Fluid may be

8 *The Motion of FLUIDS,*

once put in Motion, yet cannot they continue so: For 'tis certain, that if we take two Bodies, both moving the same Way, with different Celerities, if *A* overtakes and strikes *B*, by the demonstrable laws of Nature and of Motion, *A*, by such a Congress, must lose as much Motion as *B* acquires; and should *A* meet *B*, in a contrary Direction, with equal Velocity, being also equal in Weight, they will both stop. Wherever Resistance is, Motion is always lost; there can therefore be no *continual* Motion in Fluids.

It is moreover contrary to Observation: For Motion in Fluids of equal Density, whose Parts are every where therefore subject to equal Degrees of Pressure, is generally owing to some Agency applied, which being withdrawn, the Effect also ceases; as, from Water boiling, take the Fire, the Motion is no more. Fermentations, which occasion intestine Motions in Fluids, are only accidental; so that their Fluidity cannot be owing to any continued Motion of their Parts. Nor does Fluidity seem so much to consist in a constant and actual Motion of Parts, as in a constant and actual Mobility, or a Disposition to be easily mov'd.

THE more perfect a Fluid is, the more easily will it yield to all Impressions; and the more easily will the Parts unite and coalesce, when separated. A perfect Fluid is that, whose Parts are put into Motion by the *least* Force imaginable: An imperfect one is that, whose Parts yield to a *small* Force, not the *least*. 'Tis probable, that

that in Nature there is no perfect Fluid ; since we see that the mutual Attraction of the Parts of all the Fluids, subject to our Experiments, renders them cohesive in some Degree ; and the more they cling together, the less perfect their Fluidity is. If, for instance, a Glass be fill'd with Water above the Brim, it will visibly rise to a convex Surface, which, was it a perfect Fluid, free from either Tenacity or Cohesion, would be impossible.

MERCURY, the most perfect Fluid we know, is not exempt from this Attraction ; for should the Bottom of a flat Glass, having a gentle rising toward the Middle, be covered thin with Quick-silver, a little Motion of the Machine will cause the Fluid soon to separate from the Middle, and lie round it like a Ring, having Edges of a considerable Thickness.

BUT if a like Quantity thereof be poured into a golden Cup, it will, on the contrary, appear higher considerably on the Sides than in the Middle. Which may proceed in part, perhaps, from the Gold's being of great Density, and therefore capable of exerting thereon a greater Degree of Attraction than other Metals. Probably too it may happen from its having Pores of an apter Disposition and Magnitude to receive the minute Mercurial Particles, than those of Iron, and some other Metals ; and therefore the Attraction of Cohesion in this Experiment may obtain also : And every one knows how easily these two Bodies incorporate, and make a perfect
Amal-

Amalgama. But the Reason commonly given for the two last Phænomena is, that Mercury, in the first Case, attracts itself more than it does Glas; and, in the last Case, Mercury attracts Gold more than it does itself.

OUR Sir ISAAC NEWTON was no doubt a *Prima-materialist*, and held all Matter to be originally homogeneous; and that from the different Modifications and Texture of it alone, all Bodies receive their various Structure, Composition and Form. In his Definition of a Fluid, he seems to imply, that he thought Fluids to be composed of primary Solids; and, in the Beginning of his *Principia*, he speaks of Sand and Powders as of imperfect Fluids.

BORELLI has demonstrated, that the constituent Parts of Fluids are not fluid, but consistent Bodies; and that the Elements of all Bodies are perfectly firm and hard. The Incompressibility of Water, proved by the *Florentine* Experiment, is a sufficient Evidence also, that each primary Particle or Spherule thereof is a perfect and impenetrable Solid. Mr. LOCKE too, in his *Essay on Human Understanding*, admits this to be so.

THIS famous Experiment was first attempted by the great Lord VERULAM, who inclosed a Quantity of Water in Lead, and found that it inclin'd rather to make its way through the Pores of the Metal, than be reduced into less Compass by any Force that could be applied. The Academicks of *Florence* made this Experiment
after-

afterwards more accurately with a Globe of Silver, as being a Metal less yielding and ductile than Gold. This being fill'd with Water, and well closed, they found, by hammering gently thereon, that the Sphericity of the Globe was altered to a less capacious Figure (as might geometrically be proved) but a Part of the Water always like Dew came through its Sides, before this could be obtained. This has been attempted by Sir ISAAC NEWTON, and so many competent Judges, on Gold and several other Metals since, with equal Success, that we do not hold any Fluid in its natural State, except the Air, to be either compressible or elastic.

The HYDROSTATICAL PRINCIPLES
demonstrated.

ALTHOUGH the Original, the Constituent Parts of Fluids, may be very probably of the same Nature with those which constitute other Bodies, and essentially have the same Properties as they; yet in external Forms and Circumstance, we see they often differ: Since fluid Substances frequently become consistent; as Water is changed into Ice; the Sap and Juice taken in by the Fibres of the Root, into the woody Parts of Trees, &c. and melted Metals, &c. afford Instances, that fixed Bodies may, in the like manner, be made fluid. In one Circumstance however all material Substances, on which Experiments have been made, do certainly agree, *viz.* they consist of Particles that have Weight; and
whatever

whatever be the Form, Texture or Disposition of their Parts, their Gravity is always proportionable to the Quantity of Matter they severally contain. This is an universal Property, of which Matter is not to be deprived; and if in some Fluids, that Gravity does not immediately appear to Sense, 'tis because the lower Parts, by sustaining and buoying up the upper, hinder their Descent: Nor will it follow, that because this Gravity is not immediately perceptible by us, that therefore the Parts of Fluids are really without Weight.

NOTHING is less felt, perhaps, than the Weight of the Air; but yet, if we exhaust the Air from a Vessel, poise it at the Arm of a fine Balance, and let the Air into it again, we shall find that Air does gravitate, even in the Air; and that the Axiom of the Schools, *viz. That Elements do not gravitate in their proper Places, that is, in the same Elements*, is absolutely a Mistake.

In like manner it may be shewn, that Water gravitates in Water. Take a Glass Bubble, and so poise it with Shot till the upper Part shall swim just level with the Surface of a Jar of Water; hook it on a Horse-hair, fixed to a Balance-Beam, on which it will then lay no Weight; fill it with Water, and a considerable Difference of Weight will appear, *viz.* that between the Weight of the Air extruded, and that of the Water admitted: All which may serve to confirm our first Principle in HYDROSTATICKS, namely, *That all*

all Parts of a gross Fluid, as Water, &c. whatever be their Situation, Circumstance or Position, gravitate, and are heavy.

AND since all Fluids have Weight, there is no room to doubt, but that their upper Parts continually gravitate and press upon the lower; the Pressure whereof is always in direct Proportion to the incumbent Matter, or to the Quantity of the Liquor above the Parts propos'd. *The deeper therefore a Fluid is, the greater is its Pressure; not only on the Bottom of the Vessel, but also on the Parts of the intermediate Fluid:* Which is our second hydrostatick Principle, of itself sufficiently evident.

Now all Quantities of a Fluid may be properly consider'd as divided into many other intermediate imaginary Surfaces, lying parallel to the upper and nether Surface thereof, and level with the Horizon. For example; take a long Glass full of Water, as *Fig. 1. Plate 1.* which, for the Sake of Illustration, may be divided by Threads at equal Distances; call the first Division, *A*; the second, *B*; the third, *C*; and so on. Suppose each Division contains an Ounce of Water, the Surface then at *B*, will be press'd by one Ounce; that at *C*, will support two; that at *D*, three Ounces; and the Bottom will lie under the Weight of four Ounces of Water.

Now, whenever a Fluid is of the same kind, and incompressible, it will be of equal Density in all its Parts, which will all therefore continue

at

at rest, each being as low as of itself it can be: Since 'tis certain, that an Impulse of one Ounce in *A*, cannot of itself descend and displace two in *B*; nor can two in *B*, overcome three in *C*; nor those thrust away four in *D*.

AND as a Quantity of Water, hydrostatically consider'd, may be distinguish'd by imaginary Surfaces, parallel to the Horizon; it may be also conceiv'd, divided into imaginary Columns, perpendicular or vertical to it, in manner resembling a Bundle of Reeds. These being all of the same Height and Weight, will equally press in every Part each of the imaginary fluid Surfaces beforementioned, and cause them, no less than the upper Surface, to lie level with, and parallel to the Horizon. And consequently, if a Body, of the same specifick Weight with a Fluid, be therein immers'd, 'twill remain in any Part thereof indifferently, and keep its Place, wherever 'tis put.

To illustrate this, let us suppose a Cubick Inch of any Matter, of the same specifick Gravity with Water, put, for Example, nine Inches under the Surface; the imaginary Surface immediately beneath it, will be press'd with nine Inches of Water, and an Inch of a Body specifically of the same Weight with Water: But every other Part of that Surface, the same in Depth, sustains the Pressure of ten Inches of Water; therefore the said Inch of solid Matter will there lie at rest, and neither sink or rise.

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To demonstrate this by Experiment, we may charge a Glass Bubble, made of Matter specifically heavier than Water, partly with Air, and partly with Water, that it may become equal in Weight to a like Bulk of Water with itself. If that be done, 'twill lie indifferently, either at Top, in the Middle, or at Bottom of a Jar of that Fluid, wherever it is put. And thus may our third hydrostatical Principle be proved; namely, *That in homogeneous Fluids, that is unmix'd, or of the same kind, all Parts are naturally in a State of Rest.*

OUR fourth Principle is, *That the lateral or side Pressure of a Fluid is equal to the perpendicular.* For as the Pressure of a Fluid against the Bottom of a Vessel, is proportion'd to the Height of the Fluid in that Vessel; so is the Pressure of a Fluid, against every Side of a Vessel, in a like Proportion to the Height of the Fluid, above the Part consider'd.

To illustrate this, let a cylindric Vessel be suppos'd fill'd with an incompressible Fluid, having no Gravity, and this be forced down with a proper Piston, the Fluid would endeavour to spread; but being confin'd by the Sides, could not. The Bearing, in this Case, against all Parts of the Vessel, must be justly equal to that Force wherewith the Piston is driven. Suppose then Gravity restor'd to the Fluid, and the foremention'd Pressure continu'd, the nether Parts will then sustain a greater additional Pressure than the upper, from the Gravity restor'd; and that in Proportion to the Height

Height of the Fluid above the Part assign'd, according to our second Principle fore-mentioned.

THIS Proposition may be tolerably well demonstrated by a Vessel, having a Hole of a certain Bigness in the Bottom, and another of the same Dimensions as near the Bottom as may be, fill'd with Water to any Height; let the Plugs be pull'd out and put in both at the same time, and if, upon Comparison, equal Quantities of Water nearly shall have been yielded by them, 'twill shew the Force wherewith it issued to be also equal, and sufficiently confirm our fourth Principle in Hydrostaticks, *viz. That, at all Deptbs, the lateral Pressure of a Fluid is equal to the perpendicular.*

THE equal Pressure of Fluids against all the Sides of a containing Vessel, might also appear, by freely suspending a deep Vessel of Water, not over-heavy, by a String, hanging a Plumb-line, also at Liberty, parallel, near it: Upon making a Hole in the Side, the Vessel, which, before such Opening was made, had a perpendicular Direction, will then recede from it; the lateral Pressure of the contained Fluid being, on the Side of the Opening, diminish'd.

THE Rising of a Rocket in the Air is also occasion'd by a like Inequality of Pressure. The Gunpowder being set on Fire, turns to a very elastic Vapour, whose Parts endeavour to recede from each other equally every way. As the Case is strong and close shut above, and only open where the Flame issues below, it is less press'd a
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great deal by the Air without it, than by the Rapidity of the Flame, bearing against the Sides and Top of the Rocket within; which Difference of Pressure has sometimes carried a well-made Rocket, of no more than two Ounces in Weight, four hundred Yards high, with as much Thread veer'd out at the Tail as determin'd the Quantity of its Rise. For the same Reason, in the Discharge of a Cannon the Force of the Powder acting against the Breech of the heavy Gun, and not being counterpois'd by an adequate Pressure forwards, sends out the Ball, with a precipitate Velocity: And if the Charge of Powder be over-great, or the Piece not truly bored, it then commonly recoils, upon the same Account.

IN Fluids at rest, each imaginary Surface is every where equally press'd; and whenever it happens otherwise, the imaginary Surfaces most press'd, will give way and retire, and those less press'd will be forced upwards and rise. The sinking of a Stone in Water, is an Evidence of the one; and the swimming of a Cork, an Instance of the other.

BUT to demonstrate this Matter plainer: Take a Tube of Glass, an Inch or more in Diameter; tie a pliant Bladder loosely over the End, and put it down any Depth in a Jar of Water. So long as the imaginary Surface of the Water, at the End of the Tube, is less press'd by the Air within, than it is elsewhere by the Atmosphere, and a Column of Water of equal Length with the immers'd Part of the

C

Tube,

Tube, the yielding Bladder will be pushed upwards, and become convex within. Let Water then be poured into the Tube, to the same Height and Level with the upper Surface of the Water in the Jar; or lower the Tube so that the included and external Water may be in the same Level, the imaginary Surface before-said being then equally press'd in every Part, the Bladder will appear level; but should the Fluid in the Tube be rais'd above the upper Surface of the Water in the Jar, the imaginary Surface beneath the Tube, being there harder press'd than in any other Part, the Bladder will bag down, and become convex without.

ONCE more: Take a Glass Tube, and suspend in it a small Quantity of coloured Water, that the Effect may be more visible; which may be done, provided the Bore be not over-large, by stopping the upper End with the Finger. The Machine, so charged, immerse to any Depth in a Vessel of clear Water. The nether End of the Tube will then reach to, and rest on an imaginary Surface, by which 'twill be press'd upward with a Force just equal to the Weight of the small Pillar of Water thereby thrust away and displaced; but every other part of that Surface will be press'd by collateral fluid Columns, all of equal Weight and Altitude. If then the Pipe be unstopped, the Air, which on Immersion of the Tube represents and kept the water out, will be expell'd; and the Water, being the weightier Fluid, will push into, and rise in the Tube till it is of a just Level with the rest of the Water

in the Vessel. And again, if this Water be therein retain'd, stopping it as before, on bringing the lower Orifice of the Pipe near the upper Surface of the Water in the Jar, the Fluid will, when the Tube is unstopped, immediately subside, and become of the same Level with the Water in the Vessel: Which will prove, Fifthly, *That if any Part of a Fluid be more press'd than another, the heavier will sink till the Equipoise be restored.* As the former Experiment evinced, *That the lighter Parts of a Fluid, or those less press'd, will rise till an Equilibrium is obtained, if nothing obstruct.*

It may at the same time be farther demonstrated, that the lateral Pressure of Fluids, and the perpendicular both upwards and downwards, are also in a direct Proportion to their Heights, by Tubes bent to favour that Intention; as in *Fig. 2. Plate 1. A, B, C, D*: And the Effect produced will on Experiment be the same in all, proceeding from a like Cause, viz. the equal Gravitation of homogeneous Fluids, which exerts itself every way, and every way equally.

This may be farther demonstrated, by covering with a wet Leather a smooth Weight of Lead of any regular Thickness, as *B, Fig. 3. Plate 1.* made to fit the Mouth of a large Tube, as *A*; to which, at its first Immersion, let it be kept so close as to admit no Water, by a String. By the time it is about twelve times its own Depth under Water, it may be let go, and the

Push of the Water upwards will support it. If it be put lower, it will adhere more strongly; and if shallower, it will, for want of a due Counterpoise, fall away.

AND as Bodies heavier than Fluids may be thus made to swim; so may Bodies lighter than Fluids be retained at any Depth in them, provided they cannot insinuate, and get beneath, to force them up. For instance; a round Trencher will remain at Bottom of a Pail of Water, equal to itself in Diameter, if it be so well fitted as that without sticking no Water can get under it. And a flat Glass, with only a Drop of Oil or other Liquor between, will remain at the Bottom of a Jar of Mercury, if the Bottom be flat also, tho' the Glass be six times lighter than that Fluid, Bulk for Bulk. The Oil, &c. put between the Glass Planes, is only intended to fill Irregularities and Vacuities; for which, were they exact Planes, there would be no occasion.

ONE general Consequence of our Principles thus prov'd is, *That Fluids will always rise to their own Level, or endeavour so to do.* This is what the Antients were ignorant of; and therefore they usually built Aqueducts (vast Rows of Arches one above another, between two Hills, at a vast Expence of Money, Time and Labour) in order to convey Water over them, cross the Valley, in a common Channel. This is now done to equal advantage, and at much less Expence, by a range of Pipes laid down one Hill and up the other.

AN Instance whereof may be given by a bent Tube, a Crane or Syphon; into one of the equal Legs whereof if Water be poured, it will rise to the same Level exactly in the other. The Reason is obvious: In the Leg *A*, Fig. 4. Plate 1. there are suppose two Ounces of Water endeavouring by the Power of Gravity to descend with the Force of 2; these will thrust forward, buoy up, and support an equal Quantity of a like Fluid in *B*; and the Bottom of the Machine *C*, against which both Sides equally bear, will of consequence sustain a double Pressure, or that of four Ounces; and in the present Case will pretty well represent the Prop or fix'd Point of a Balance-beam; as the equal fluid Columns *AC*, and *BC*, may be admitted to denote equal Weights, suspended on the Balance-arms, counterpoising each other. So that the Rise of Fluids to their first Level, thus consider'd, is a Case truly Statical; and all their other Motions proceed only from Weight added.

THE Pressure of Fluids is in Proportion to their perpendicular Heights only, and not according to their Quantity. For instance: There can lie no greater a Pressure against the Dikes that fence out the Sea in *Holland*, or against the Banks of the *Thames* or the *Danube*, in calm Weather, than there does against the Sides of any Vessel fill'd to an equal Depth with the Water just mentioned; respect being only had to the Quantity of the Surface so pressed.

To demonstrate this; Take a Glass Vessel *A*, of the same Bigness, or cylindrical from Top to Bottom, Fig. 5, Plate 1. toward the lower Part
C 3 whereof

whereof let a Glass Pipe be fix'd, which, by Help of the Joint *F*, will be capable of any Degree of Elevation. Supposing the Diameter of the Tube but the hundredth Part of the Diameter of the Jar (the Capacities of Circles being in Proportion to each other as the Squares of their Diameters) the Fluid in the Pipe will be but a ten thousandth Part the Quantity of that in the Jar wherewith it communicates; and yet, if the Jar be filled to any Height, the Altitude of the Water in the Pipe, whether erect or inclined, perpendicularly taken, will be exactly in the same Level with that in the Jar, and always lie in the Line *C D*. Whence 'tis evident, that a small Quantity of a Fluid, provided it be equal in Height, is able in certain Circumstances to counter-balance any Quantity of the same Fluid; and the Reason is this:

THE Bore of the Pipe of Communication is of a certain Bigness, we will suppose the tenth of an Inch in Diameter; by the Structure of the Machine there can at the same Time press no more of the Jar-water against the Orifice thereof, than one Pillar equal in Height and Dimensions to the Pipe; and it was before demonstrated, that such a Pillar will drive forward, and in the same Level sustain a Pillar of Water equal in Weight and Size to itself: Which is the Case before us exactly. And did the Tube communicate with the main Ocean, the Effect would be still the same.

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SHOULD we however fill a hundred Inches of our Pipe with Water, and by a Cock or other Contrivance admit it singly into the Jar, 'twill raise the Fluid therein only one tenth of an Inch, and this ten times repeated will raise it only an Inch. Whereas on the contrary, should we, by thrusting a Piston or a tight Cork into the Jar, depress the Body of the Fluid therein contain'd but the hundredth Part of an Inch, the Water would thereby be forced into the communicating Tube to the Height of ten Inches; and by a still greater Pressure, should it be sunk in the Jar a tenth of an Inch, 'twould rise a hundred Inches in the Tube. Whence it appears, that this is also a case nicely Statical, resembling the Effect produced by the Steelyard; on which Machine if one Pound be hung at the distance of a hundred Inches from the Fulcrum or Prop, it will counter-balance and to a Level raise a hundred Pounds, at the distance of but one Inch; and just the contrary. For to make the larger Weight by its Rise or Fall to move an Inch, the other must traverse the space of an hundred Inches; the Velocities of the Weights being always reciprocally proportional to the Quantities of Matter in them severally contain'd. Whence it in general follows, that the Pressure of Fluids is always truly estimated, when the Perpendicular Height of the Fluid is multiplied into the Area of the Surface it bears or presses upon, whether laterally or perpendicularly consider'd.

The HYDROSTATICAL PARADOX.

A Due Consideration of the last-mentioned Case gave Birth to the *Hydrostatical Paradox*; whereby 'tis asserted, *That since all Fluids, press according to their perpendicular Altitudes, and not according to the Bulk or Quantity of their Matter, the Pressure of a contained Fluid against the Bottom and Sides of the containing Vessel will always be proportionable to the Height thereof, whatever Form it be of; and the same as if it was really of the same Bigness from Bottom to Top.* To explain which, take a Cylinder of a certain Base, that will hold perhaps a Pint; as *A*, Fig. 6. Plate 1. This Vessel being fill'd, the Bottom will be allow'd to sustain the whole Weight of the Fluid therein contained; Gravity always acting in a right Line, and perpendicularly. Again, take another Vessel of equal Height and Base with the former, partly cylindrical, and partly flanch'd out into a Portion of an inverted Cone, as *B*; this Vessel suppose will hold a Quart. Then take a third Vessel of equal Base, but cylindrical thereon only half way; to make it however of equal Height with the other two, let a small Pipe be soder'd into the Lid, as *C*: let this Vessel contain in the whole but half a Pint. If these be severally filled with a Fluid of the same kind, we say that the Bottoms and Sides of each of these shall be pressed thereby alike; and beginning with the second, we prove it thus.

As

As all homogeneous Fluids, or those of equal Density, are proved by our third Principle to be naturally every where at rest, was the Tin-work of the cylindrical Part of our Vessel *B* continued through the conical Part thereof to the Top, according to the prick'd Lines in the Draught, the Fluid thereby enclosed would be just in the same Circumstances of that in the Vessel *A*, and then the Side-water, contained in the conical Part, would bear against our Cylinder, supposed continued to the Top, as if the Water therein was frozen on the one Hand, and the Tin Sides of our conical Part on the other, according to the Height of the Fluid between them contained. Imagine then the Continuation of our Cylinder removed, or the Water frozen therein to thaw; the Pressure of the Side-water would then lie against the fluid Cylinder itself, which being in all Parts of equal Weight and Moment or Force with itself, will be thereby sustained quiet and motionless in its proper Place. And 'twill be supported on the other Side, in like manner by the sloping Sides of the Vessel, which being rigid, will sustain the Quantity of the Pressure made perpendicularly thereon: Nor would the Weight on the Bottom, or the Push against the fix'd cylindric Sides of this Vessel within, be at all encreased by the Alteration proposed.

It must however be admitted, that as there is double the Quantity of Matter, by Supposition, contained in a Vessel of this Form, that was in the cylindrical Vessel *A*, the absolute Weight of the

the whole together will be proportionable thereto. But then it must be considered, that this Increase of Weight and Pressure affects only the shelving Sides of the Vessel *B*; and as these by their Disposition become an inclined Plane, they are doubtless made to bear the Difference of Weight proposed, which must be thence communicated to, and supported by the upright Sides of the cylindric Part of *B*, whereon they rest: But on the Area of the internal Base of *B*, and against the Sides of the Cylinder within, as has been said, no more Weight is laid than barely what is answerable to the perpendicular Height of the Fluid above them,

LET us next consider how a like Pressure may be made on the Bottom and Sides of the Vessel *C*, containing but half of the Fluid in *A*, and but a fourth Part of that of *B*. Supposing the Parts of a Fluid, as doubtless they are, globular, the Particles of the Water will be well represented by the Draught, *Fig. 7. Plate 1*, wherein 'tis certain, that the central Column *AB* presses, according to our fourth Principle, not only perpendicularly upwards and downwards, but laterally also, and in every Direction alike; and consequently all the Rows of Particles lying next the Bottom of the Vessel, must be all impell'd thereby equally toward the Sides.

To prevent Confusion; let us distinctly consider the Effect of this Pressure on one single Rank of these Particles, which may be applied in like manner to the rest. The lower Particles then of the Column *AB* gravitate on those
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adjacent, and thrust them, for example, from *B* towards *C*. At *C*, finding themselves confin'd, their Effort will not there cease, but be transferr'd, and made to press upward toward *D*, against which Part of the Lid a Push will be made, just equal to the Difference of the Pressure of the two Columns consider'd, *viz.* *AB* and *CD*; the first of which gravitates with the Force of 2, being supposed twice the Height of *CD*; which therefore presses but with the Weight of 1. The Impulses being yet unequal, will not stop here; but the Particles will be thereby laterally pushed from *D* towards *E*, where meeting with others in the same Level of equal Force and Moment with themselves, will, being there equipoised, remain at rest.

THE Gravity then of the Particles contained in the central fluid Column *AB*, acting against the Lid of the Cylinder in every Part, and the Lid reacting in like Manner against the whole Body of the Fluid below, as great a Pressure is thereon laid as if the Cylinder had been continued to the Top of the Pipe, and thereby fill'd.

ON pouring Water into one Leg of the Syphon, it will rise, we know, to the same Level in the other. This may be applied here, by supposing a Pipe as high as the Neck fix'd in some Part of the Lid of our Cylinder, as at *D*. On Opening the Plate in that Place, as much of the Fluid will be pressed up immediately therein, as will bring it to a just Level with that remaining in the Neck; which being again

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replenished, the other will also be filled. Whence 'twill be evident, that before the said Opening was made, the Pressure beneath the Cover of the Cylinder in that particular Point, was equal to the general Pressure by the middle Column laid on every Part of the Surface of the Fluid in the same Plane, that is, in the Level of the Lid. There is therefore Reason to believe, that was the Lid set entirely full of such Pipes, the Fluid in the Neck of the Machine would descend in like manner, and fill each of them equally to a certain Degree: This, in effect, would be raising the Lid. And should the Neck be several times thus successively replenished, it would by degrees fill them all; which is much the same thing as compleating the Cylinder, and filling it up.

A single Pint of Water may this way then be so disposed as to be of equal Force and Pressure with some Gallons; and this the following Experiment will put past all Doubt.

THE small Quantity of Water in the Tube *B*, *Fig. 5. Plate 1.* is, we know, in that Situation, a Counterpoise to ten thousand times the same Quantity in the Jar. This may also be applied to the solving our Hydrostatical Paradox. Let us stop up the Mouth of the Jar with a tight Cork, having a Glass Pipe thrust therein, as *E*, by which with a Funnel let the Jar be gradually filled; as the Fluid rises in *A*, 'twill advance proportionably in *B*, and preserve a just Level in both. That done, proceed to replenish the

the Tube *E* also, and the Water continuing then to rise also equally in *B*, will demonstrate that it is still impelled by the same or an equal Force, and consequently that the Pressure on the Bottom and against the Sides of the Jar, is the same as if it were lengthen'd out to *E*, and filled. And the Experiment succeeding on a Vessel of this Shape, leaves no doubt but 'twill always do so; since this Figure seems to be the least advantageous to it that can be contrived.

AN Experiment to the like Purpose might also be made by perforating the Bottom of two Vessels, a Cone suppose and a Cylinder, both equal in Base and Height, with Holes equal in Diameter. Let them be kept constantly filled; unstop and stop them both at the same Instant, and they will be found both to have discharg'd equal Quantities of Water in the same Time. And if the Efflux of so even a Fluid as Water, from these Vessels, be found equal; the impellent Force, by which it is pushed forth, may with good Reason be presumed equal also.

HERE indeed it may be objected, that it being mathematically demonstrable, that a Cylinder of equal Base, and of the same perpendicular Altitude with a Cone, is in Capacity or Content thereto as three to one. And should such a Cone, containing no more than two Pounds of Water, have its Bottom and Sides as much pressed thereby, as will those of the Cylinder by six Pounds of that Fluid; it should seem, that, provided the Pressure of the Fluid in the

containing Vessels, and the Weight of the containing Vessels themselves was also equal, their absolute Weights, when full, ought to be equal also: To suppose which, in a Cone and Cylinder of equal Heights and Bases, would be absurd.

To this we reply: That the absolute Weight of Bodies is not affected by their interior Disposition or Circumstances: For though the Pressure on the Bottom and against the Sides of the tapering Vessel, be three times as great as is the Weight of the Water therein contained; yet does it not follow, that it should be three times as heavy. For a Whalebone, a Spring, or any other elastic Body, much bent and forced into such a Vessel, will not in the least augment its absolute Weight, by bearing internally against the Sides and Bottom with any Force whatever.

In like manner it may be understood, that the Water included in a conical Vessel, may press the Bottom and Sides, without increasing the positive Weight of the whole. For supposing the Water in the conical Vessel *ABC*, *Fig. 7. Plate 2.* divided into several Frustums or Portions of a Cone, *E, F, G*, parallel to the Base; from what has been said, 'tis plain that the Bottom, *BC*, will be as much press'd by the Water in *G*, with that in *F*, assisted by the Re-action of the inclined Sides *AB* and *AC*, as if it had been continued cylindrical to *HI*: And the same holding good with regard to the rest, it follows, that against the Bottom and Sides of the Vessel as great a Pressure will be made, when full of a
Fluid,

Fluid, as if it had been a compleat Cylinder, and fill'd up to *K L*.

It may perhaps also be objected, That if a Vessel, having a Pipe inserted in the Lid, and filled with Liquor, suffers the Pressure spoken of; that a Pipe of the smallest Diameter, a capillary Tube, or one no bigger than a Hair, ought to produce the same Effect: Which is contrary to Experience.

To this we answer: That the Pressure in the Case thus proposed, is indeed not the same; and the Reason is, because all our Liquors are imperfect Fluids. They have all some Tenacity, Attraction, and Cohesion in their Parts, of which they cannot be divested, and which are by Experience found to prevail very much where the Tube is small, that is, where most of the Parts of the liquid Column rais'd come into Contact with, or touch it; such Tubes therefore suspend and even raise Water: Whereas in those of a larger Diameter, and such wherein the Weight of the fluid Body over-powers the Attraction of the Cohesion, this will be scarcely sensible; and there the before said Experiment would have its full Effect. As it would doubtless also have, even in the Case of the capillary Tube, if Water were a perfect Fluid, and there was no Attraction from the Tube.

On the ATTRACTION of Cohesion.

IF the Bore of a Pipe be even an eighth of an Inch in Diameter, the Attraction spoken of will be very apparent : For on immersing the End in some Fluid, and taking it out again, a great Part indeed will quit the Tube ; but some will still remain, and hang therein. And if we take several small Glass Tubes different in Size, and immerse them together in Liquors, those of the smallest Bore will attract the Fluid most, and it will be found therefore always to stand the highest in them.

THE same Cause which inclines Fluids to rise in small Tubes above the Level of the rest, which they very notably do, makes them descend also in the Filaments or Threads of Cloth, in the way of Filtration ; which sooner takes effect if the Pores of the Cloth be first filled with Liquor. The Cells of Bread, Sugar, and other porous Substances, for a like Reason imbibe Fluids plentifully ; in which they rise, against the Direction of Gravity, for the Reason just assigned.

THIS Attraction will be very notable in an Experiment upon a Crane or Syphon of a small Bore. If one of the Legs of this Machine be immers'd in a Jar of Water, the Fluid, as in small Tubes it does, will rise therein, and sensibly stand something above the common Level of the rest : And if the Jar be filled with Water to
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Brim, the Difference spoken of will take place in the Bend of the Syphon ; which when it shall have past ever so little, (and if the Tube be first wetted within, this will soon happen) Gravity will then lay hold, and pushing out the Air before it, bring it down ; after which the Water will continue to rise through the Bore of the Machine, like a continued Thread, till it shall have emptied the Vessel to the Depth of the immers'd Leg ; the Reason whereof comes next to be enquired into. But previous to this, the specifick Gravity of Fluids ought a little to be consider'd.

On SPECIFICK GRAVITY.

AS an equal Bulk of a heavier Fluid will sink in a lighter with a Force proportionable to the Difference of their Weights ; so will a lighter counterbalance, repress, and even raise a heavier, provided a proportionable Quantity thereof equal or superior to it in Weight, be to that Purpose applied.

FOR instance ; Water is heavier than Oil, in the Proportion of about eight to seven, that is to say, eight Inches of Oil equipoise seven of Water ; Water therefore will sink in Oil ; and on the contrary, Oil on Water will swim. Now as seven Inches of Water are in *Equilibrio* with eight Inches of Oil, if a Tube with Water in it, be put level with the upper Surface of a Jar of Oil, about a seventh of it will drop out and sink ;

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the rest will be buoyed up, and remain just supported therein. And should the like Experiment be made on Water, having Oil in the Tube, the Oil will be buoyed and weighed up above the Surface of the Water about a seventh Part.

MERCURY, again, is near fourteen times heavier than Water; yet when we suspend a little of it in a small Tube (as by stopping out the Air's Pressure at Top may with Care be done) on putting it about fourteen times it's own Depth in Water, 'twill not drop out of the Tube, when unstopp'd above; but if it be put deeper, will be rais'd therein, and if brought shallower, will drop out, according as the imaginary Surface of the Fluid beneath the Tube shall be more or less press'd by the Weight of Mercury, than the other Parts of it are by the collateral Pillars of the Fluid, wherewith it is in these Experiments compared.

On the SYPHON.

IF a small Syphon, whose Legs are of equal Length, be fill'd with Water, and turned downward, the Fluid will not run off, but remain suspended therein, so long as it is held exactly level: But when an Inclination to either Leg is given, whereby one in effect is made shorter than the other, the Water will shoot out by the longer Leg forthwith.

THE Air is a Fluid whose Density near the Surface of the Earth is experimentally found to be to that of Water, at a Medium, as 1 to 850; so that eight hundred and fifty Gallons of Air, near the Earth, weigh as much as one Gallon of Water. Now, according to the Nature of all other fluid Bodies, the Air presses the Surface of all Things exposed to it every way equally. When therefore the Legs of the Syphon, equal in Length, are turned down, (the Weight of the Atmosphere above being kept off by the Machine) the under Air, bearing against and repressing the Water, endeavouring to fall out of either of them, with equal Force, keeps it in suspence, and prevents its Motion. But when by inclining it to either Side, we in Effect shorten one of its Legs, and prolong the other, an Advantage is given to the weightier Fluid to preponderate or over-weigh; the Water then begins to descend, and by its Continuity brings away the whole: Just as pulling one End of a Thread, will make the whole Clue follow.

AND to observe how small an Inclination will serve this Purpose, one need only take a couple of Jars full of Water, and hang a small Syphon, whose Legs are of equal Length, upon the Edge of one; the external Leg whereof will, from the sloping of the Jar, naturally incline a little, and the Syphon will soon begin to act, by the Attraction of Cohesion before-mentioned; then taking it on the Edge of the other Jar, the like will immediately happen: And thus reciprocally

may the Effect be produced, as often and as suddenly as you please.

AND hence the Reason why in Practice the Legs of the Syphon are usually made of unequal Lengths ; and why the shorter Leg is put into the Liquor, and the Fluid decanted by the other, will in part appear.

'TIS evident from what has been said, that the two Legs of the Syphon, *Fig. 8. Plate 1.* being of equal Length in the Plane *AB.* are there equally repressed by the Atmosphere; and was the Crane fill'd with Liquor only to that Height, and held level, no Motion of the Fluid would follow, 'til an Advantage by inclining it should be given as before-said. Instead of which Inclination a Length of Pipe, of some Inches perhaps, as from *B* to *C* in the Figure, is commonly added to these Machines, which, previous to the Operation, is ordinarily fill'd as well as the rest with a gross Fluid, many Degrees heavier than a like Quantity of Air, wherewith it is then compared ; by the Gravity whereof the opposite Side becomes greatly over-balanced : And therefore Liquors are by this Machine usually decanted with a good deal of Rapidity.

BUT as the Air's Pressure is a Thing in this Treatise as yet not fully proved, it may not be amiss in this Place to make an Experiment, which may shew the Action thereof on the Surface of the Fluid raised, by substituting a visible Substance, *viz.* Oil of Turpentine, in its room
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wherein *KL*, *Fig. 3. Plate 3.* is a large glass Jar, capable of receiving the following Apparatus, *viz. AB*, which is a smaller Jar of Water heavier and more pellucid than Oil, and *GH* an empty Jar, into which the Liquor between *A* and *B* may be decanted by means of a Syphon whose Legs are made unequal for the Purpose, as above said; in the Bend whereof is an open Tube fix'd, as *EF*. The Water will on Immersion naturally rise by its own Weight in this Machine to *C*. Then let Oil of Turpentine be gently poured into *KL*, after *GH* has first been fill'd therewith, and the Water will at length be raised to the Bend at *E*, by the Pressure of the Oil still lying about one seventh above it, as suppose in the Level of *NM*. The Air at first contain'd in the Syphon, will, as the Liquors rise, be gradually protruded from either Leg, through the open Tube at *F*. The Water then being specifically heavier than the Oil, with which it then meets within the Syphon, will sink down the Tube *ED*, and in Time the Water from *AB*, will be apparently decanted into *GH*. And thus will the Principle on which the Syphon acts, be confirmed, by the Action of two visible Fluids, different in Weight, upon each other.

THE Way of making this Experiment with best Success, will be to stop the End of the Tube at *F*, before either of the two Liquors, get into the Legs of the Machine, lest the lighter Fluid the Oil, by rising faster in *DE*, than the counterpoising Water in *EC*, and by first taking Place in the Bend, might there so gravitate, as absolutely to prevent the rising of the Water

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thither at all. But, by the Way now proposed on removing the Finger suddenly, the Air somewhat compressed in *F*, by the Weight of the grosser Fluids endeavouring to enter the Syphon will in Part thereby escape, and the two Liquors meeting thereupon with a kind of Shock, the more ponderous will sink through the other, and produce the Effect desired: 'Twill be proper also, that the small Jar be almost full of Water, and of Height sufficient to clear the longer Leg of the Syphon, when the Bend comes to rest on its Brim; or otherwise the Oil, by taking Post previously in the Bend, may chance to frustrate the Experiment.

On the SYPHON disguised.

BEFORE we proceed farther on this Subject, let us attend to some of the Varieties in which the Syphon may appear. It may, for example, be disguised in a Cup, from which no Liquor will flow till the Fluid is raised therein to a certain Height; but when the Efflux is once begun, 'twill continue 'till the Vessel is emptied. For instance; *Fig. 9. Plate 1.* is a Cup, in the Center whereof is fixed a glass Pipe *A*, continued through the Bottom at *B*, over which is put another glass Tube, made Air-tight at Top by means of the Cork at *C*; but left so open at Foot, by Holes made at *D*, that the Water may freely rise between the Tubes as the Cup is fill'd. Till the Fluid in the Cup shall have gained the Top of the inmost Pipe at *A*, no Motion will appear: The Air however from between the two Pipes, being in the mean time extruded, by the Rise of the denser Fluid, and passing down the inner Tube, will get away at Bottom, and the Water

Water, as soon as the Top of the inclosed Tub^c shall be covered thereby, will very soon follow, and continue to rise in this Machine, as in the Syphon, till the whole is run off.

THIS is called by some, a *Tantalus' Cup*; and to humour the Thought, a hollow Figure is sometimes put over the inner Tube, of such Length, that when the Fluid is got nearly up to the Lips of the Man, the Syphon may begin to act and empty the Cup.

THIS is in effect no other than if the two Legs of the Syphon were both within the Vessel, as in *Plate 1. Fig. 10.* into which the Water poured will rise in the shorter Leg of the Machine, by its natural Pressure upwards, to its own Level; and when it shall have gain'd the Bend of the Syphon, it will come away by the longer Leg, as already described. An Apple, an Orange, or any other Solid, may be put into the Vessel to raise the Water, when it is near the Bend, to set it o' running, by way of Amusement.

THERE are other artful Ways of diversifying and concealing the Syphon, to make its Effects appear the more strange and amusing; but as they all depend on the same principle, 'twill be sufficient only to describe one of the best. Let the Handle of the Cup, *Fig. 11. Plate 1.* be hollow; let the Tube *CD*, screwed therein, communicate freely with the Water poured into the Cup, that it may rise equally in both. Being once above the Level *ED*, 'twill overflow, and descend

scending through the Cavity *D B*, will empty the Cup of its Liquor.

On NATURAL SYPHONS

SOME uncommon Phænomena in Nature may be accounted for upon this Principle. There is for Instance a Pond near *Gravesend* in *Kent*, out of which the Water actually ebbs all the Time the Tide is coming into the adjacent River, and into which the Water ordinarily flows during the Time the Tide is going out of the *Thames*.

THIS Appearance is occasioned, no doubt, from there being somewhere in the Bank a subterranean Reservoir, equal in Capacity to the whole Rise and Fall of the Water in the Pond. This Reservoir, when empty, may not improbably be fill'd from the River, pretty near the Top of the Tide, through some proper Conveyance in the Bank,

BETWEEN this Reservoir and the Pond, from the accidental Disposition of the Parts of Matter in that particular Place, there may very probably be some natural Syphon, whose Bend lying something lower than the Surface of the Water in the Reservoir, when full, may by the Rise of the Water therein, have the Air gradually protruded from the shorter Leg; and when the Water is once above the Bend, 'twill soon shoot down and dispossess the longer of it. The Syphon will thereupon begin to act, and may continue thereby to replenish the Pond during the whole

whole Tide of Ebb, by which Time the Reservoir being exhausted, the Syphon will gather Air, and cease to act.

THE Pond being thus fill'd to a certain Height, 'tis not unlikely but that a second natural Syphon, concealed in the Earth somewhere near the Pond, whose Bend also lying something lower than the Surface of the Water in the Pond, may in like manner begin to run, about the Turn of the Tide in the River; and continuing so to do all the Tide of Flood, discharging itself into some subterranean Passage that carries it off, may easily produce the odd Phænomenon now describ'd.

THERE is also among others a Spring in Derbyshire, called *Wedding-Well*, or *Tydes-Well*, of which Mr. COTTON, in his *Description of the Wonders of the Peak*, gives the following Account.

IT is, says he, a small and to Appearance an inconsiderable Spring constantly rising at the Foot of an Hill, which on occasions, after a rumbling kind of Noise heard as under Ground, runs so briskly as to make a pretty smart Torrent. It usually flows in this manner for about three Minutes, and issues with a singing kind of Noise resembling that made by the playing of a *Jet-d'Eau*.

HE takes Occasion to inform us, that Mr. HOBBS was of Opinion, that this temporary Flux could not proceed from the Sea, because the Water was intirely fresh; and such was its Irregularity, that it could not be under the Influence
of

of the Tides. But says he conjectures, that in the Passage of the Spring, there might probably be some narrow Vent, which in wet Weather might not be able to receive all the Water that came down; he therefore imagines, that the Air there pent up, might also by endeavouring to oppose its Passage, cause it to heave as if convulsed, to lie as it were gargling there, and so occasion the Rumbling mentioned under Ground.

BUT to this Account Mr. COTTON himself objects, That was this the Cause of the Appearance before-cited, it would never happen but in wet Seasons, and the Water would also be sometimes thick and muddy; both which are observed to be contrary to Fact.

THIS remarkable Phænomenon happens, it must be observed, at a great distance from the Sea, and much above it, in a very mountainous Country. Now the Hills generally intercept and retain the humid Particles, or the Vapours floating in the Air, and driven by the Winds, whether it rains or not. In this Country there are several vast Caverns in the Belly of the Hills, found to have Water continually trickling down the Rocks, as well within the Earth as without. In the Case before us, it is then very probable, that a natural Reservoir, not over large, may be concealed somewhere within the adjacent Hill, and so conveniently placed as to receive the descending Waters. This being fill'd by the Drippings before said to a proper Height, some natural Syphon may then
begin

to run, and the Water descending through the subterraneous Vents, issues as before describ'd. The Syphon perchance happens to be pretty large, and therefore causes it to come down briskly as in a Torrent. Thus upon rational Principles, and with great Probability may be explain'd, what seem'd so great a Difficulty to Mr. COTTON and Mr. HOBBS.

AT *Lambourn, quasi Lame-bourn in Berkshire*, again, there is a Brook, which in Summer-time is known to receive a Flow of Water sufficient to turn a Mill; but during the Winter, it runs with a very inconsiderable Stream. 'Tis probable that this proceeds likewise from some very large subterraneous Reservoir, which the Winter Snows and Rain, in a Length of Time, may fill to a certain Height; and then some large natural Syphon may take Effect, and bring away its Water in a Stream equal to the Dimensions of the Bore. And when the Reservoir is by that Means exhausted, what runs afterwards may be no more than the Weeping of the adjacent Springs.

*The Use of the AIR'S PRESSURE in
raising FLUIDS.*

BEFORE we leave this Subject, we ought to be satisfied, That 'tis the Air's Pressure on the Surface of Fluids which principally makes them rise in the Syphon. This Machine we are to observe is always to be Air-tight; otherwise the Air admitted, though in Quantity ever so small,

small, being of the same Force and Density with that adjacent, will counter-balance the Weight of the Atmosphere acting upon the Surface of the Fluid to be decanted, and immediately cause the Motion to cease. To demonstrate this, we need only take out the Cork C, stopping the exterior Tube, when the Syphon of our *Tantalus' Cup*, Fig. 9. Plate. 1. is in Action, and the Flux will thereupon immediately cease.

THIS may be farther evinced, by running off a Phial of Mercury through a Syphon fix'd into the Cork, into which a short Quill is also put, by way of Ventage, to let in the Air, and continue the Pressure of the Atmosphere successively on the Surface of the decanted Fluid. So long as the Quill remains open, the Mercury will run off with great Freedom; it can no sooner be stopp'd, but the Flux of the Fluid will be so too.

It may not be unacceptable to the Curious nevertheless to intimate, That however the Air's Pressure be the true and general Cause of the Rise of Liquors in the Syphon, yet will they also rise, under certain Circumstances, and to certain Limits, *in Vacuo*, when that Pressure is withdrawn. This has been already hinted to be owing to their being imperfect and tenacious Fluids, subject to the Attraction of Cohesion, which between some Bodies is more prevalent, between others less. And this may be easily try'd on a Jar of Water, by a small Syphon *in Vacuo*, and from the Discharge then made a

Judg-

Judgment may be in part formed how great the Tenacity of Water, and what the Attraction of the Glafs thereon is: For was it a perfect Fluid, and the Attraction fufpended, it could not, *in Vacuo*, be fupposed to rife or run at all.

THE Way of making this Experiment with Succefs is, not abfolutely to fill the Veffel brimful of Water at firft; but, by help of a Wire paffing through a Collar of Leathers, when the Air is pretty well exhausted, let down fomething folid into the Water, which may raife it to the Brim, and fet the Syphon o' running. By this the Liquor may be decanted nearly perhaps to the Depth of the Leg immers'd, provided the Syphon be very fmall: If it is any thing large, this will never happen in any Degree.

THE like may be try'd upon Mercury, by help of an Apparatus that will keep the Syphon from swimming. This may be effected by fixing a piece of a ftrong wooden Tube like a Hoop, exactly fitting the upper Part of your glafs Jar. On one Side of which let there be a fmall Groove, juft wide enough to receive the glafs Syphon, which may afterwards be closed with a convenient Slider, and a little Cement if occafion be, both to confine your Mercury and keep your Syphon fix'd. Then filling up your Jar with Mercury to a convenient Height, and exhausting the Air, let down your folid Body abovementioned into the Jar, to raife the Fluid fomething above the Bend of the Syphon, and it will begin to run, as before. By obferving then

then how much of the Mercury will run off thereby, and comparing it with the Quantity of Water before discharg'd, the Difference of the Tenacity of these two Fluids, and their Attraction to Glass, as was said, will in part appear, if the same Syphon be used in both Experiments, and the Thing accurately done.

Now as the Air's Pressure near the Earth, by several undeniable Experiments may be proved at least to be equal to the absolute Weight of thirty-three Feet of Water, it will at all times counterbalance, and therefore raise and sustain that Quantity for Service. It will actually do so in the Pump, and in the Syphon would very probably do so, was it necessary to apply it in that manner: So that a Fish-pond, or any other Head of Water, might be run off thereby, over a Dyke, much above the Surface, if a Sough or Drein, to carry it off otherwise, could not be made.

WATER will rise in the common Air in a Jet, when over-balanced by the Spring of Air compress'd. Air of the common Degree of Density, will produce a like Effect in Air attenuated or more rarefy'd, as by proper Experiments hereafter will be shewn. As an Instance of the latter kind, at present, however take the Machine, *Fig. 12. Plate 1.* in Form not unlike and in reality differing but little from the Syphon; except that where the Legs communicate, there is a transparent Vessel fixed, through which a rising Jet of Water may be seen. Into this Part of the Machine,

chine, thro' either of the Legs, first pour a small Quantity of Water, which when the whole shall be revers'd, will miss the Hole of the jetting Pipe *A*, communicating with the Vessel *C*, and make its Way down the longer Leg *E*, through an adequate Opening made at *B*. The shorter Leg is at the same Instant to be put into the Jar of Water *C*. Upon this the Vessel *D*, before fill'd part with Water, and part with Air, by the falling away of the Water, which it was before charged with, will be fill'd with Air only, a small Matter thus rarefy'd and expanded. The Atmosphere then pressing the Surface of the Water in the Jar with its whole Weight, and the inward Air, thus attenuated, resisting with but a diminished Force, will cause the Water to rise from the Jar into the glass Head; whence continuing still to descend by the longer Leg *E*, the Machine will agreeably play a Jet of Water, so long as there is any Liquor left in *C* for a Supply.

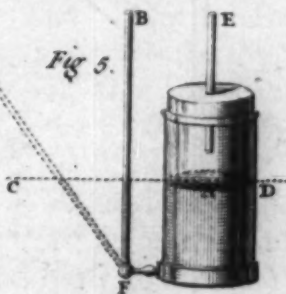
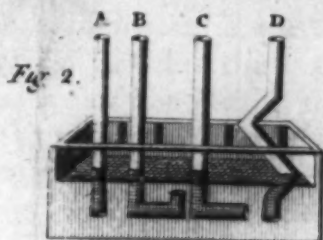
On SUCTION *by* MACHINES.

THE Quantity of the Air's Pressure may be demonstrated either by Experience on the Pump itself, or by its equipoising and at a Medium sustaining twenty-nine Inches and a half of Mercury, a Fluid near fourteen Times heavier than Water, in the common Barometer. And the way we know that 'tis the Air's Pressure on the Surface of the Fluid, whereby the Water is raised, by the Pump; and become certain that

that it proceeds from no Property, Power or Efficacy in Suction is, that in the Air, Water, and even a Fluid so dense as Mercury, may be raised by proper Machines: But if the Air's Pressure be removed, it cannot be raised at all; as may be shewn by an Exhausting Syringe, (so call'd to distinguish it from the Forcing or Injecting) commonly term'd a Sucking Syringe, or if you please a common Pump. Let this be fix'd to a transparent Tube, and the nether End thereof put into a Jar of Mercury, inclosed within a tall Receiver; before the Air is exhausted, if the Piston be raised, the Mereury will immediately follow; after 'tis exhausted, no such Effect will appear.

THIS being determin'd and certain, all then we are to understand by Suction is, That whenever by any mechanical Disposition or Contrivance, the Pressure of our surrounding Fluid, the Air, is in any Place abated, the adjacent Matter, urged on by the Weight of the Atmosphere, will tend thither; and if that Matter be yielding and fluid, 'twill so far rise above its common Level, as till, by it's absolute Weight, a just counter-balance is made, in order to preserve the Equilibrium, which ought every where to exist, by the established Laws of Nature and Providence.

BEFORE GALLILEO'S Time, Philosophers fancied this Rise of Water and other Fluids, to be the Result of *Nature's abhorring a Vacuum*. Not to cavil at the Term *abbor*, which can only properly be apply'd to animal Affection; but to take



as it was probably intended, in a metaphorical Sense: We may reasonably enquire, How Nature came to abhor a *Vacuum*, in the Case before us, to the Height of between thirty and forty Feet, from the Surface of the Earth, and no farther? Had she absolutely abhorred a *Vacuum*, this Abhorrence would have been indefinite; and Water, upon this Principle, might have been raised three thousand, as well as thirty Feet high. But this is otherwise in Fact. And by Experience we find that Nature has no Antipathy to a *Vacuum*; but that in general, *One heavy Body only rises, when another superior in Weight descends.*

THE Rise of Water in the Sucking-pump, by the general Pressure of the Atmosphere incumbent on the Surface of the Water in the Well, a Pressure not to be excluded from the Bowels of a Body so porous as the Earth, being thus settled, the Parts of this Machine, with the Manner in which they act, will next come under Consideration.

On the PUMP.

THIS useful Piece of Mechanism was first invented by CTESEBES, a Mathematician of *Alexandria*, about a hundred and twenty Years before Christ. When the Air's Pressure came afterwards to be known, 'twas much improved; and 'tis now brought to a great Degree of Perfection.

OF this Machine there are simply three Kinds, *viz.* the Sucking, the Forcing, and the Lifting-pump. By the two last, Water may be raised to any Height, with an adequate Apparatus and sufficient Power: By the former it may, by the general Pressure of the Atmosphere on the Surface of the Well-water, be raised no more than thirty-three Feet, as was before hinted, tho' in Practice it is seldom apply'd to the raising it much above twenty-eight; because from the Variations observ'd on the Barometer, 'tis apprehended that the Air may on certain Occasions be something lighter than thirty-three Feet of Water; and whenever that shall happen, for want of the due Counterpoise, this Pump may fail in its Performance.

On the SUCKING-PUMP.

THE common and most usual Pump, consists of a Pipe open at both Ends, in which there is a sliding Piston as big as the Bore, which by means of the Hand, or some other Contrivance, may be moved up and down without suffering any Air to come between it and the Sides of the Pipe; which is otherwise call'd the Barrel, as *AB* in *Fig. 2. Plate 2.*

If the lower End of this Pipe and Piston be put into Water, and the Piston raised, by Lifting away the Column of upper Air, a *Vacuum* will be made in the Pipe, upon which the Atmosphere pressing on the Well-water, will

will force it to follow the Piston, even to the Height of thirty-three Feet, could the Stroke be of that continued Length; and if there be a Valve or Clack, something like a Trap-door, to shut downward, as *Fig. 1. Plate 2.* placed in some convenient part of the Pipe below the Water so raised, as at *C, Fig. 2. Plate 2.* 'twill certainly be retained therein. But if this Contrivance be wanting, upon shoving down the Piston again, the Water will recede along with it towards the Spring: So that by the Motion of the Piston up and down, the Water indeed might rise and sink in the Barrel at every Stroke; but without an under Valve to confine and keep it there, none can be drawn for Service, in the common Way.

THE Frame *A* of these Valves, *Fig. 1. Plate 2.* is usually made of Wood, exactly fitted to the Bore of the Pipe, and not over-thick, that it may not stop too much of the Water-way. To this the Hinge of the leather Flap *B*, which is usually lined with Lead, not only to make it fall readily, but to give it Strength sufficient to bear the Weight of the Water raised without warping, is commonly nail'd.

IN this kind of Pump there is, besides this fix'd Valve, a moveable one for Conveniency's sake placed in the Piston, as at *D, Fig. 2. Plate 2.* also opening upwards, or the Way the Water is to rise. Such a Piston is commonly call'd the Bucket.

WHEN the Bucket of this Machine descends, if the Bore of the Pipe be already full of Water, the Resistance thereof will push open the moving Valve, and part of the Water will get above; and whenever the Piston is drawn upwards, this Valve will close under the incumbent Weight, and the Water will be raised by the Force applied: So that whenever the moveable Valve by being raised, is made to lift the Weight of the Column, as well of Air as Water lying thereon, the fix'd Valve is discharged of all Pressure; and then a Quantity of Water, precisely equal to that by the Bucket lifted and drawn off, will by the ordinary Pressure of the Atmosphere, as was said, on the Water in the Well, be forced or rather weighed up through it, to replenish the Pipe or Barrel. This alternate Action of the two Valves is visible thro' the glass Pumps, and is worthy of Remark.

BUT if the Bore of this Machine be full of Air only, before Water can be drawn that Air must be exhausted; which may be done, if the Piston-valve be tight, by the ordinary Motion thereof: But for the greater Certainty and Expedition, Water is commonly poured thereon down the Pipe, vulgarly call'd *Fetching the Water*; which is of no other Use than to wet the Valves and supple the Collar of Leather fixed to the Bucket or Piston, and spread it that it may lie close to the Sides of the Barrel, and suffer neither the upper Air or Water to escape by it, when 'tis moved up and down.

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THE first Stroke of the Pump, if sufficiently long, will make a total *Vacuum* in the Pipe; if otherwise, an Approach is only made towards it, and but a Part of the contained Air lifted away; upon which the Air remaining in the Cavity of the Bore, from it's natural Spring, will be considerably dilated. To restore the natural Density whereof, the Atmosphere then pressing harder on the Well-water than does the dilated Air on that in the Pipe, will cause the Water to rise therein so far, as that, together with the included Air (yet a little rarefy'd by the depending Weight of Water) it shall just counterpoise the Weight of the outward Air. The very same Thing will again happen on a Repetition of the Stroke, till by Degrees the Water shall have reached the moving Valve; and then the Process will go on steadily as before described. And Water, by means of this Contrivance, may be raised to any Height whatever, if the Power applied be sufficient to lift the Weight, and the Pipes strong enough to bear the Fluid's lateral Pressure.

THE Pressure on the Pipes in Pump-work, has already been proved under our fourth principle Page 15 to be in Proportion to the standing Height of the Fluid above the part considered: But the Weight incumbent on the Bucket or moving Valve of a Pump, in Action, is nearly proportionable to that of the Column of Water raised. For tho' the Push of the Atmosphere on the Surface of the Spring, when the Bucket rises, be really equal to the Weight of thirty three

Feet of Water; yet is this Assistance counter-balanced exactly by the Weight of the Atmosphere, ever incumbent on the Surface of the Water thereby raised: So that all the Advantage to be obtained by, or expected from Hydraulick Machines, or Engines to raise Water, as well indeed as from all other Pieces of Mechanism whatever, is only the putting Matters into a convenient Method of being executed, and the Performance depends on the moving Power intirely, under the Disadvantage of Friction always against it.

On the Disposition of PUMP-WORK.

A Pump therefore intended to raise Water to any Height whatever, will always work as easy, and require no greater a Power to give Motion to the Bucket, if both the Valves be placed towards the Bottom of the Pipe, than if they were fixed thirty-three Feet above the Surface of the Water.

THE playing of the Piston thus low in the Pipe, will besides prevent an Inconvenience which might happen was it placed above, viz. in Case of a Leak beneath the Bucket, which in a great Length of Pipe may very easily happen, the outward Air getting thro', would hinder the necessary Rarefaction of the Air in the Barrel, on moving the Piston; and consequently the Pump might fail in its Operation. This can only effectually be prevented by placing the Pump-work in or near the Water. In which Case,

Cafe, should any Leak happen upward, 'twill only occasion the Loss of some of the Water, without any other Inconvenience. And the leather Valves being thus kept under Water, will always be found supple, pliant, and in a fit Condition to perform their Office.

It may indeed be here objected; That the specifick Weight of the iron Rod, to which the Bucket is fixed will be an Incumbrance to the working of the Pump: But if it be made of Oak, when well soak'd, 'twill be nearly of the same specifick Weight with Water, and so no Burden on the moving Power, when the Stroke is fetch'd.

PLACING the Pump-work, that is the Valve and Piston, pretty low and near together, will also prevent the Inconvenience of our not being able in all Cases to fetch up Water from the Spring, by the ordinary Pump, when of an equal Bore; by Reason of the Shortness of the Stroke, which therefore cannot rarefy the Air sufficiently to bring the Water up to the Piston from the nether Valve. For Instance: Take a smooth barrell'd Pump, twenty-one Feet long, having its Piston fetching suppose a Foot-stroke, plac'd above, and the Clack or fixed Valve at the other End below. By the playing of the Piston, admit it possible for Water to rise eleven Feet, or if you will, let Water be poured on the Clack, to the Height of eleven Feet; and refit the Piston. There will remain still nine Feet of Air between it and the Water, which cannot be sufficiently rarefy'd by a Foot-stroke, to open the Clack,

or fetch up any more Water : For in this Case, the Air can only be rarefy'd in the Proportion of 9 to 10; whereas to make a bare Equilibrium with the Atmosphere, it ought to be as 9 to $13\frac{1}{2}$: Since, as 22, or the Complement of 11, to 33 Feet of Water, the Weight of the whole Atmosphere, is to 33 Feet, or the Atmosphere; so is the Interval spoken of, 9, to $13\frac{1}{2}$; to complete which, the Stroke ought to be at least $4\frac{1}{2}$ Feet long.

HOWEVER, by filling the whole Void between the Piston and Clack at first with Water, this last Objection might be removed.

On the DISPOSITION of PIPES of CONDUCT.

IN some Cases the Pump cannot be placed conveniently perpendicular to the Well : For Example, being to raise Water out of the Well at *A*, *Fig. 3. Plate 2.* by Means of a Pump at *B*; the best Way will be to carry the Barrel as low as is the Spring, communicating therewith by means of the Pipe at *C*. The Bucket then playing in the Barrel at *BC*, will have the same Effect, as if the Well was made perpendicular to the Pump : Because the Water, by its proper Weight, will always replenish *BC*, thro' *A*, to the Level of the Well-water at *F*.

AND if it should happen, from some considerable Impediment, that the Barrel cannot go down

down to the Well directly, it may be led about any other way for sake of Convenience. And then making the Pipe of Conveyance *E*, less in Diameter than the Barrel, it will sooner be exhausted of Air, by moving the Piston, and the Water will follow very briskly, as by the leaden Pump at *D*.

It will, however, always be more easy to draw Water with Pipes that are large, and of an equal Bore throughout; because the Water will have a less Velocity in them, and the Friction will be in Proportion less. Upon this Account, the Pumps ordinarily made by the Plummers, go not so easy as those bor'd out of Trees: Because, by making their Pipe that brings up Water from the Spring so much less than the Bucket, they as it were wire-draw the Water rais'd. If the Barrel, for Instance, be four Inches in Diameter, and the Pipe of Conduct one, it will in rising move sixteen Times as fast thro' this, as it will in that, to the Expence of needless Labour, as well as the great Wear and Friction of the Machine.

For the like Reason, it will be also a Fault to bore a Pump conically upward, because the Water cannot with Freedom get away so fast as a *Vacuum* by the moving Piston may be made; and the Reflection of the Water from the Sides, will be always a Hindrance to the Operation.

In Practice however 'tis generally observed, that such Leaden Pumps as work pleasantly, and
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are light upon the Hand, have the Water-way in the Sucking-Pipe, nearly equal to one fourth of the Area of the Barrel; and accordingly an Inch and half Pipe will pretty well supply a three Inch Barrel: And a four Inch Barrel should have a leading Pipe, nearly two Inches in Diameter.

On LEATHERING the PISTONS.

ANother Mistake the unskilful Workman is very apt to make, is leathering the Piston so stiff, as to bear so very hard against the Sides of the Barrel, as to wear it much away, commonly called *Chambering the Pump*. However, such a Machine may be very tight, it will, on Account of the great Friction, require more Labour to work it than is necessary.

THE Sole-leather of a Shoe is found strong enough to resist any reasonable Pressure from above, as in the Case of the Sucking and Lifting-Pump Pistons; or to overcome any Thrust made below, as in the Case of the Piston of the Forcing Pump, and will last a long Time.

THE way of leathering the Pistons of these Machines, is always so as to face their Work; that when the Strain comes, the Leather, being a strong, and tough, yet yielding Substance, may spread, and suffer neither Air nor Water to pass between the Pistons and the Sides of their Barrels, when they are moved. If the Pump be to work hot Liquors, coarse Cloth is commonly used instead of Leather for this Purpose.

On the LIFTING-PUMP.

THE Structure of the Lifting-Pump, *Fig. 4.* *Plate 2.* differs from that of the Sucking-Pump in nothing but the Disposition. As that has its fix'd Valve below, and the moveable one above, in the Barrel *AB*, *Fig. 2.* *Plate 2.* this is just the contrary, as *C* and *D*. As the Bucket or Piston of that is moved by a Rod within the Bore of the Pipe, this is so by means of a strong Frame fixed to a Rod without at *E*. As in that, 'tis of Advantage, for fear of a Leak, to have the Pump-work, if possible, in or near the Source of Water; this in Practice is commonly so done, and for that Reason is very seldom subject to any Failure in its Performance. An Elbow in this kind of Pump, to lead the lifted Water clear of the playing of the Rod, which of Necessity must move perpendicularly, is unavoidable. The Friction occasioned hereby will however always be less the nearer this Bend comes to a straight Line.

FROM the Name and Structure of this Machine, it may be imagined, perhaps, that the Air's Pressure is not of equal Service to this kind of Pump, as to the former; but it is quite otherwise. For if both Valves be not perfectly Air-tight, Water cannot be well raised thereby: But in Case neither of them is defective, Water will be raised to very good Purpose, by much the same kind of Process as that of the Sucking-Pump,

Pump, before explained. Nor is there any doubt, but that if two Machines, a Sucking and a Lifting-pump, were made of equal Bores; wrought with equal Force, and were in every Circumstance alike, they would be found of equal Service in raising Water.

N. B. The Representations of the several Pistons, and their Valves, in the common Pump-work, are express'd in the Draughts sufficiently plain, and all disposed in their proper Actions, when the Machines work.

On the FORCING-PUMP.

AND as the Weight of the Atmosphere is of very great Use in the two Pumps already described, it is of no less Advantage to the Forcing-pump; which consists, as in *Fig. 5. Plate 2.* of a Barrel *AB*, a Piston or Forcer *C*, leather'd upwards, that it may withstand the Pressure of the Atmosphere from above, that so by sucking, when raised, it may bring up the Water to supply the Barrel; and 'tis also leather'd downwards, that, when depressed, it may resist the Weight of the Water to be forced up, or raised for Use. There are always two fix'd Valves in this kind of Pump; one in some convenient part of the Streight, otherwise called the Sucking-Pipe, as at *D*, the other in the Branching or Forcing-Pipe, as *E*. These ought in like manner to be Air-tight, and so disposed as to let

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sing

the Water freely rise, but are absolutely to hinder its Return.

WHEN the Forcer is first moved upwards in the Barrel, the Air between that and the Water below, having Room to dilate, by its natural Spring, will of course be rarefy'd therein; the Pressure of the Atmosphere then being intercepted by the Forcer in the Barrel *AB* on one Hand, and by the upper Valve at *E* in the Branching-pipe on the other, the Water will rise from the Spring into *AB*, for the Reason already given: And repeated Strokes of the Piston will fetch up the Fluid to the Forcer, and at length fill the Cavity of the Pipes between the fixed Valves *D* and *E*. This done, the Water, in this manner successively raised, being hindered from going down again by the nether Valve, will be pressed by the Forcer every Time it descends, and be thereby obliged to make its Way where the least Resistance is, *viz.* thro' the upper Valve at *E*. And whenever on the rising of the Forcer, this Pressure intermits, the Valve at *E* will immediately close under the Weight of the upper Water, and prevent its Return that Way, while the Piston is rising with a fresh Supply; and this is repeated at every Stroke of the Forcer.

On FIRE-ENGINES.

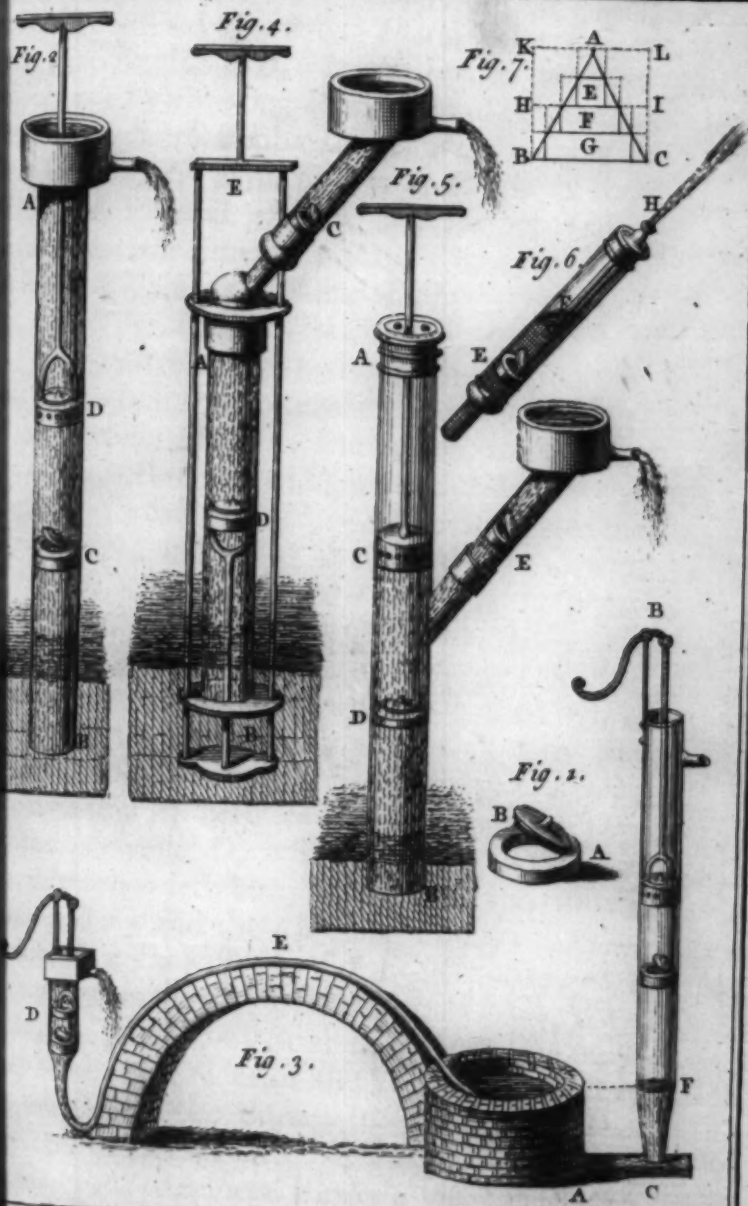
ENGINES for extinguishing Fire, are either Forcing or Lifting-Pumps, and, being made to raise Water with great Velocity,

their

their Execution in great Measure depends upon the Length of their Leavers, and the Force wherewith they are wrought.

FOR Example, *AB*, *Fig. 1. Plate 3.* is the common squirting Fire-Engine. *DC* is the Frame of a Lifting-Pump, wrought by the Leavers *E* and *F*, acting always together. During the Stroke, the Quantity of Water raised by the Piston *N*, spouts with Force thro' the Pipe *G*, made capable of any Degree of Elevation by means of the yielding leather Pipe *H*, or by a Ball and Socket, capable of turning every Way, screw'd on the Top of the Pump. Between the Strokes on this Machine the Stream is discontinued. The Engine is supply'd by Water poured in with Buckets above; the Dirt and Filth whereof are kept from choaking the Pump-work, by help of the Strainer *IK*.

A considerable Improvement has of late been made to these Machines, in order to keep them discharging a continual Stream. In doing whereof, it is not to be understood that they really throw out more Water than do the squirting ones of the same Size and Dimensions with themselves; but that the Velocity of the Water, and of Course the Friction of all the Parts, being less violent, the Stream is more even and manageable, and may be directed hither or thither with greater Ease and Certainty, than if it came forth only by Fits and Starts: The Machine thus improved, is therefore generally better adapted to the Purpose intended than the former, especially in the Beginning of these calamitous Accidents.



Fletcher Sculp.

THE Stream is made continual from the Spring of Air confined in a strong Metal Vessel *CC*, in the Fire-Engine *AB*, *Plate 3. Fig. 2.* fixed between the two Forcing-Pumps *D* and *E*, wrought with a common double Leaver *FG*, moving on the Center *H*. The Pistons in *D* and *E* both suck and force alternately, and are here represented in their different Actions; as are also the respective Valves at *IK* and *LM*.

THE Water to supply this Engine, if there be no Opportunity of putting the End of a Sucking-Pipe, occasionally to be screwed on, into a Moat or Canal, which would spare much Hurry and Labour, in case of Fire, is also poured into the Vessel *AB*; and being strained thro' the wire Grate *N*, is by the Pressure of the Atmosphere raised thro' the Valves *K* and *M* into the Barrels of *D* or *E*, when either of their Forcers ascend; whence again it will be powerfully pushed, when they descend into the Air-vessel *CC*, thro' the Valves *I* and *L* by turns. By the Force whereof, the common Air between the Water and the Top of the Air-vessel *O*, will from time to time be forcibly crowded into less Room, and much compressed; and the Air being a Body naturally endowed with a strong and lively Spring, and always endeavouring to dilate itself every Way alike, in such a Circumstance, bears strongly both against the Sides of the Vessel wherein it is confined, and the Surface of the Water thus pressed, and so makes a constant regular Stream arise, thro' the metal Pipe *P*, into the leather Pipe *Q*, screwed thereon, which being flexible,

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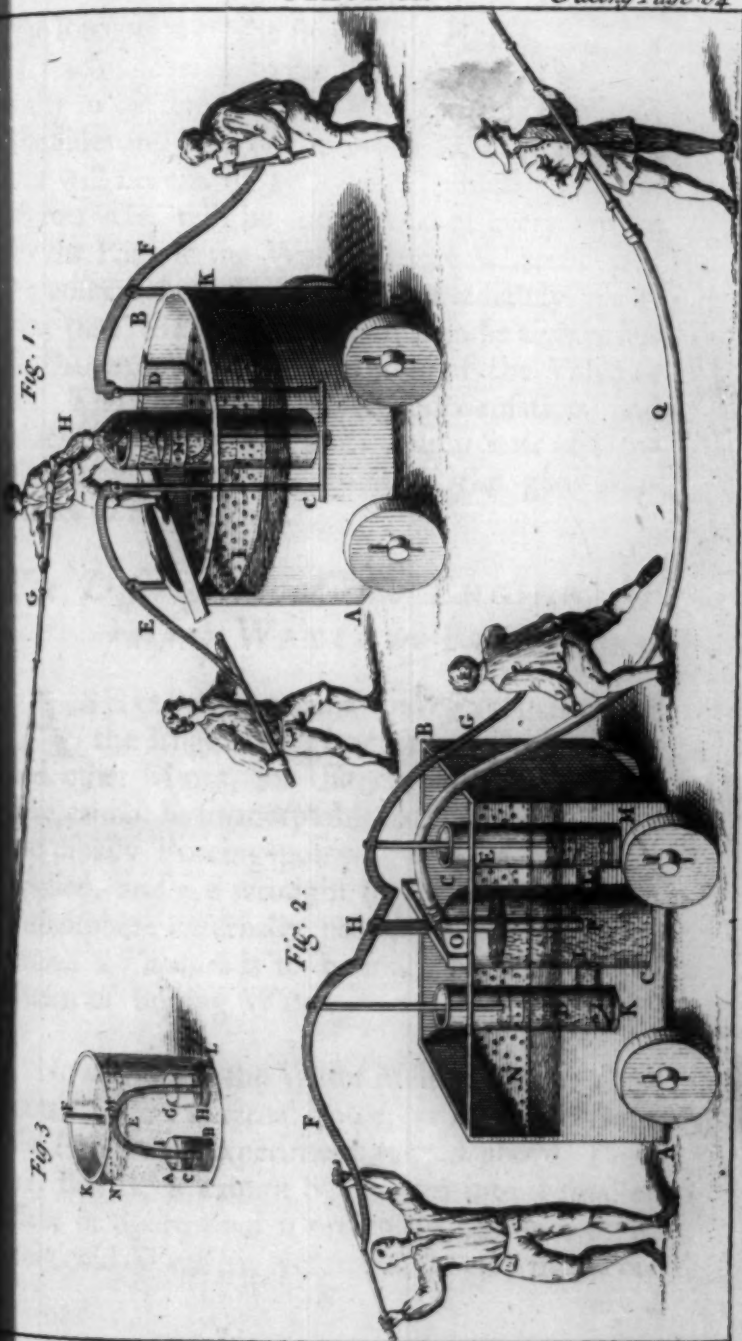
may

64 *The Motion of FLUIDS,*

may be led about into Rooms and Entries, as the Case may require.

SHOULD the Air contained in this Vessel, be compressed into half the Space it took up in its natural State, the Spring thereof will be much about doubled; and as before it equall'd, and was able to sustain the Pressure of a single Atmosphere, it having now a double Force, by the Power of that Spring alone, will throw Water into Air, of the common Degree of Density, about thirty Feet high. And should this Compressure be still augmented, and the Quantity of Air which at first filled the whole Vessel, be reduced into one third of that Space, its Spring will be then able to resist, and consequently to raise, the Weight of a treble Atmosphere; in which Case 'twill throw up a Jet of Water sixty Feet high. And should so much Water again be forced into the Vessel, as to fill three Quarters of the Capacity, it will be able to throw it up about ninety Feet high; and wherever the Service shall require a still greater Rise of Water, more Water must be thrust into this Vessel, and the Air therein being thus driven by main Force into a still narrower Compass, at each Explofion, the gradual Restitution thereof to its first Dimensions, is what regularly carries on the Stream between the Strokes, and renders it continual during the Operation of the Machine.

THIS Experiment, in little, may be either made on the Lifting or Forcing-pump, the Nossels of which may be left large, on Purpose for the



the Reception of the small Pipe *F*, Fig. 6. Plate 2. reaching nearly to the Valve at *E*, and occasionally to be screw'd in. Between this Pipe and the Sides and Top of the Nofel *H*, a Quantity of Air will necessarily be lodged, which when the Forcer acts, will be compressed at every Stroke by the Rise of the Water; more whereof will be pushed thro' *E* than can immediately get away thro' the Pipe *F*, which is to be always less in Diameter than the Opening of the Valve at *E*. The Degree of which Condensation, and that of the Restitution to its natural State of Density, may be observed through the glass Machines to Satisfaction.

The Description of the ENGINE for raising WATER by FIRE.

A SHORT Account and Explanation of the Engine of great Use in Coal-works, and other Mines, for the raising of Water by Fire, cannot be unacceptable to the Curious. They are usually Forcing-pumps, with an Air-vessel applied, and are wrought by the Weight of the Atmosphere externally pressing a Piston, under which a *Vacuum* is to be made by help of the Steam of boiling Water.

Now though the Water itself cannot be condensed by any external Force, as is evident from the *Florentine* Experiment related above, Page 11. that is, it cannot be reduced into a smaller Bulk or Space than it ordinarily has with us in very cold Weather, yet may it be very much rarefy'd

66 *The Motion of FLUIDS,*

refy'd or dilated by Heat ; as may appear on putting several small Bubbles of Glass, Metal, &c. that are of a Weight just fit to swim, into cold Water. These when the Water is set near a Fire, or over a Lamp, will sink one by one, according to their several Weights, as the Fluid warms, grows more rare, and consequently less buoyant.

By accurate Experiments 'tis prov'd, that Water may be rarefy'd near fourteen thousand Times by being reduced into Steam, the Particles whereof must be endowed with a very powerful repellent Force ; since they are able, when confin'd, to drive before them Air, and lift even a great Weight of Water to very considerable Heights.

In order to supply successively a large Quantity of Steam for this Purpose, the Machine spoken of has a large globular Vessel of Water, which, when the Engine is at work, is kept boiling over a brisk Fire, in which the Steam is close confin'd, as in *Plate 4.* mark'd with the Letter *A.*

WHEN the Steam herein becomes sufficiently dense, or strong enough for the Purpose, Part of it is let go, by turning a Cock into the hollow Cylinder *B* ; by means whereof, the Air therein contained is expell'd thro' a proper Clack, and the whole Cavity of consequence fill'd with Steam only ; which being a Body that may be condens'd again to Water, by a Jet of cold Water dispersed

disperſed among it, that which in the Circumſtance of Steam took up the Space of fourteen thouſand Pints, will this Way be reduced into that of one. By which Artifice, a *Vacuum* in the hollow Cylinder is nearly to be obtained. The Piſton then, *C*, preſſed by the Atmosphere above, will be weighed down, and deſcend with a Force equal to the Inches of the Diameter ſquar'd, and multiplied by twelve Pounds, the ordinary Weight of Air incumbent on every circular Inch near the Earth. And a Pull thus made at the End of a Leaver, equally divided at *D*, will always raiſe an equal Weight of Water at the other : So that all the while the Steam is entering *B*, the Piſton *E* ſinks and forces, and when that Steam comes afterwards to be condensed, it ſucks and riſes ; and thus alternately (fix or eight Times perhaps in a Minute) according to the Size of the Boiler, and the Intenſeneſs of the Fire that is to ſupply the Engine with Steam.

ACCORDING to the Length of the Stroke, and the Diameter of the metal Forcer *E*, a Body of Water of like Dimensions will be raiſed at every Pull, from the Spring at *Z* into the Sucking-pipe *N*, and being brought up thro' the fix'd Valve at *O*, whenever the Piſton ſinks by the Weight of the counterpoiling Liſts of Lead at *H* (occasionally to be laid on, according as the Atmosphere happens to be more or leſs heavy) will be pushed thro' the fix'd Valve in the Branching-pipe *Q* : At which time the whole Column of Water in *F* being liſted thereby, an equal Quantity will be diſcharged and

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run off at *Y*. To this Machine an Air-vessel, as *G*, may also be added, if it be thought proper, to lessen the Velocity of the Water rising in *F*; but in Draining of Mines, this can hardly be necessary.

THE Forcer of this Engine *E*, is best made cylindrical, and as long as the Stroke intended from *I* to *N*. In which Case the Collar *I*, in which it works, is leather'd both upwards and downwards, which is found to be more convenient, and yet to have the same Effect, as if the Piston was so leather'd, and made to move within a hollow Cylinder; as in the common Forcing-pump it does.

THIS Machine, according to late Improvements, begins of itself to work, as soon as the Water boils; and by little Contrivances the Motion of the grand Machine is made subservient to the Operation, either in turning the Steam out of the Boiler into the hollow Cylinder from time to time, or shutting it off; as also by letting in the Jet of cold Water, supplied when wanted, from the Cistern *K*; and by a third Device the whole may easily be stopp'd.

IF at any Time the Fire and the Steam grow too intense, to prevent Mischief from blowing up the Copper, and the like, there is a snifting Valve of a certain Weight, a little conical, put into that Machine at *L*; which when the Steam becomes too elastic or over-strong, will be thrown out, or at least raised, to give it vent.

THE

THE Segments of Circles *MM*, fixed at either End of the great Leaver, are to give the Chain to which the Piston and Forcer hang, a perpendicular Direction in all Parts of the Stroke.

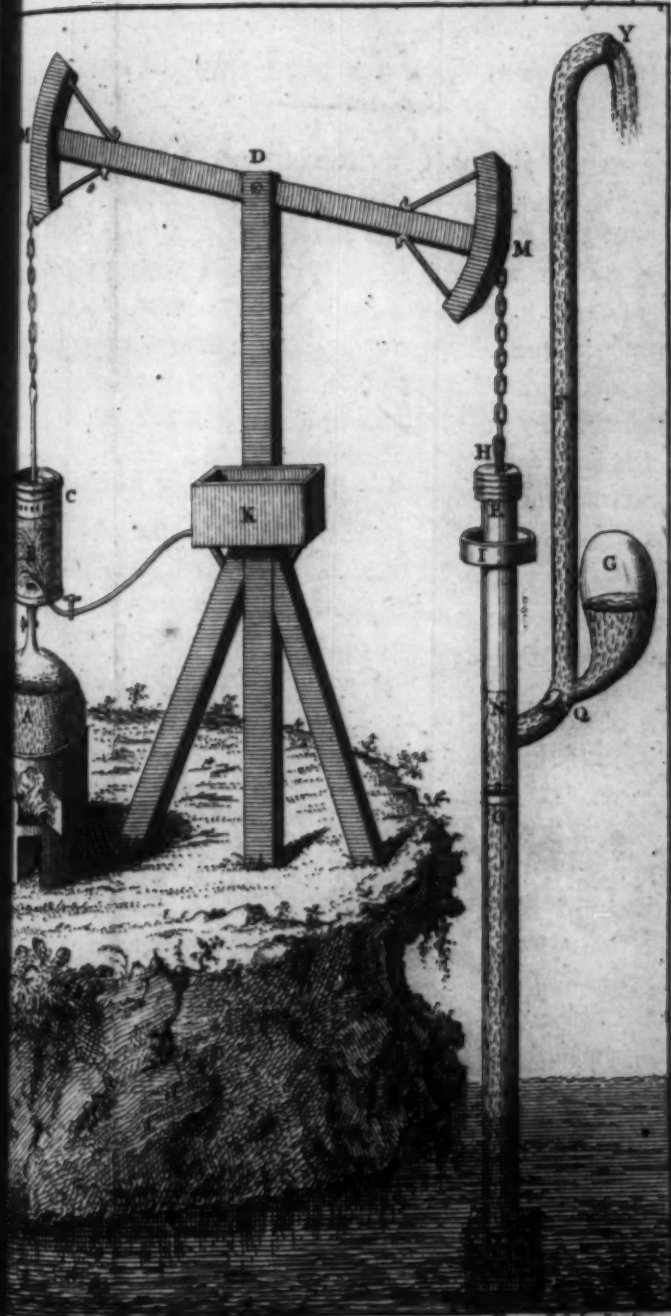
THERE is indeed a Vein of Mechanism and good Contrivance runs thro' this whole Machine; and it is very well worth considering as a Hydraulic-Engine; however, in point of Profit, it may not answer the Expectations of such as use it, where Fewel is not very cheap: For the saving whereof, a Fire-box having the boiling Water nearly round it, in the Nature of the copper Machines for boiling Tea-water, has sometimes been used with good Success.

THE original Engine for raising Water by Fire, as described in HARRIS's *Lexicon Technicum*, did not work a Forcing-pump like this; but the Vessel put here in Place of the hollow Cylinder, was first cleared of Air by a Quantity of Steam turned in thro' a Valve, which being next condensed by a Dash of cold Water thrown thereon, was then filled by Water from the Spring, which by the repellent Force of the Steam, a second Time admitted from the Boiler, was gradually lifted through Pipes annexed, to the Height intended. And this in Mines, where Room for working the great Leaver is wanting, is still in Use.

HAVING here mentioned the Strength of the steam of boiling Water, in working the forego-

ing Machine, it may not be amiss just to mention the Use it might be of in several other Cases; those especially in which the Use of Fire itself is dangerous: Such as is the boiling of all inflammable Bodies; the Distillation of spirituous Liquors; boiling of Turpentine, Tallow, Oils and Varnishes; the Drying of Gunpowder, and the like: All which Things may with Safety be done, by having the Boiler and Furnace at a Distance, or in another Room; whence by Pipes the Steam might be conveyed, and by the turning of a Cock, admitted into the Cavities of double Pans, Stills, or other Vessels fit for the Purpose intended: It may be likewise shut off, increased or abated at Pleasure by such a Contrivance, according to the Exigencies of the Case. And tho' Water itself, having once got a boiling Heat, is capable of receiving but a small Degree of Heat more than what made it boil at first; yet will the Steam arising from it be more or less heated in Proportion to the Density of it: So that it has sometimes melted soft Solder, which is a Mixture of Lead and Tin; but has never yet been able to fire Gunpowder.

MALT and other Things of the like kind, might also be dry'd this Way, and the smoaky Taste often attending these Manufactures would thus doubtless be prevented, as well as the fiery Taste very usual in distilled Liquors.



On the CHAIN-PUMP.

THERE is still another Machine for raising Water, called the Chain-pump, *AB, Fig. 1. Plate 6.* 'Tis ordinarily made from twelve to twenty-four Feet long, and consists of two collateral square Barrels, and a Chain of Pistons of the same Form, fixed at proper Distances thereon. The Chain is moved in these round a coarse kind of Wheel-work at either End of the Machine, the Teeth whereof are so made as to receive one half of the flat Pistons, and let them fold in; and they take hold of the Links as they rise in one of the Barrels, and return by the other. The Machine is wrought either by the turning of one Handle or two, according to the Labour required, depending on the Height to which the Water is to be raised. A whole Row of the Pistons (which go free of the Sides of the Barrel, by perhaps a Quarter of an Inch) are always lifting when the Pump is at Work; yet do they by the general Push in the ordinary Way of working, as 'tis pretty brisk, commonly bring up a full Bore of Water in the Pump. This Machine is so contrived, that by the continual folding in of the Pistons, Stones, Dirt, and whatever happens to come in the Way, may also be cleared; and therefore it is generally made Use of to drain Ponds, to empty Sewers, and remove foul Waters, in which no other Pump could work.

*On the ENGINE for raising WATER by
a MULTIPLYING-WHEEL.*

IT would be endless to consider and describe the Mechanism and all the Contrivances of Engines for drawing of Water. The general Principles whereof being well understood, the Use and Application of all Machinery for that Purpose, will easily be discerned. The Description however, and Sketch of an Hydraulic Machine, that has no sort of Dependance on the Action of the Atmosphere; but which, by the Weight of Water only, and without Pump-work of any kind, raises Water sufficient to serve a Gentleman's Seat in *Buckinghamshire*, with an Overplus for Fountains, Fish-ponds, &c. (executed by the late Mr. GERVES) it is to be hoped the Curious will easily excuse.

A and *B* in *Plate 5*, are two copper Pans or Buckets of unequal Weight and Size, suspended to Chains, which alternately wind off and on the Multiplying-wheel *YZ*; whereof the Wheel *Y* is smaller in Diameter, and *Z* larger, in Proportion to the different Lifts each is designed to perform.

WHEN the Buckets are empty, they are stopp'd level with the Spring at *X*, whence they are both fill'd with Water in the same Time.

THE greater of the two, *A*, being the heavier, when full, preponderates and descends ten Feet perhaps from *C* to *D*; and the lesser, *B*, depending on the same Axis, is thereby weighed up or raised from *E* to *F*; suppose thirty Feet.

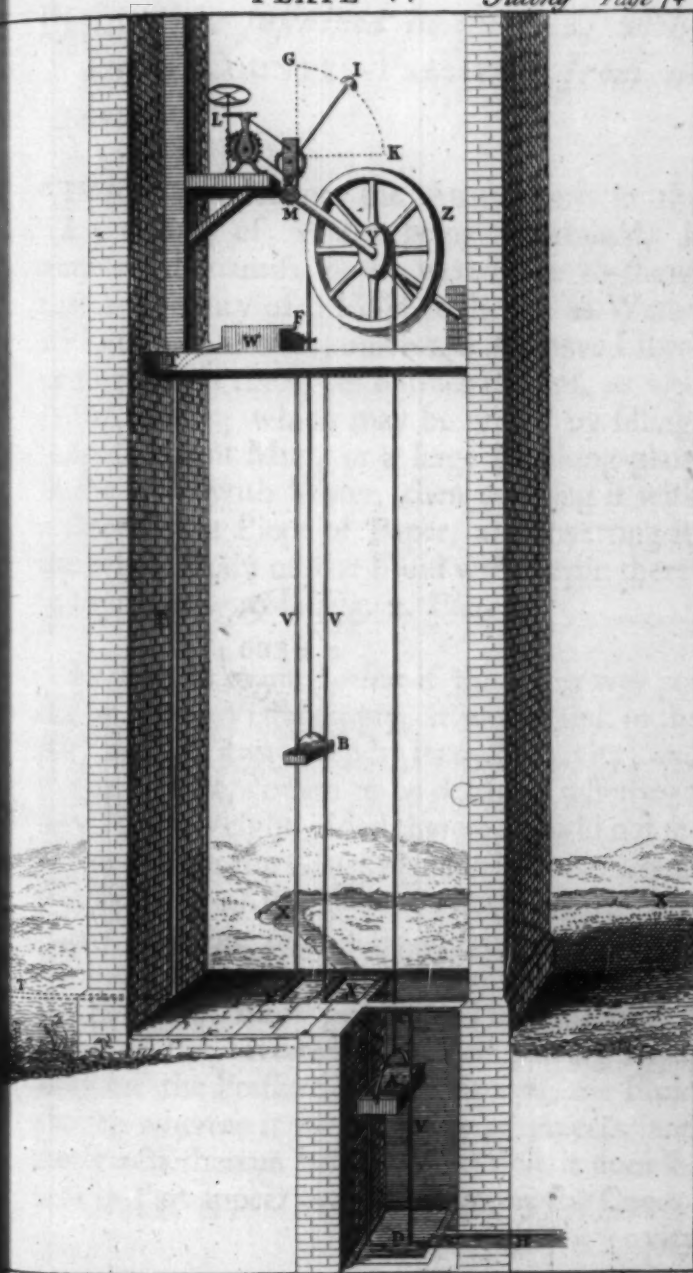
HERE, by particular little Contrivances, opening the Valves placed at Bottom of each of these Buckets, they both discharge their Water in the same Time thro' Apertures proportionable to their Capacities; the smaller into the Cistern *W*, whence 'tis conveyed for Service by the Pipe *T*, and the larger at *D*, to run waste by the Drain below at *H*. The Bucket *B* being empty, is so adjusted as then to overweigh, and descending steadily, as it rose betwixt the guiding Rods *VV*, brings or weighs up *A* to its former Level at *X*, where both being again replenished from the Spring, they thence proceed as before. And thus will they continue constantly moving (merely by their circumstantial Difference of Water-weight, and without any other Assistance than that of sometimes giving the Iron-work a little Oil) so long as the Materials shall last, or the Spring supply Water.

THE Steadiness of the Motion is in Part regulated by a Worm turning a Jack-fly, and a little simple Wheel-work at *LM*, which communicating with the Multiplying-wheel Axle at *M*, is thereby moved forward or backward, as the Buckets either rise or descend. But what principally

principally keeps the whole Movement steady, is the Equilibrium preserved in the whole Operation by a certain Weight of Lead, at the End of a Leaver of fit Length, and fixed on one of the Spindles of the Wheel-work, the Numbers whereof are so calculated as during the whole Performance up and down, to let it move no more than one fourth of a Circle, from *G* to *K*; by which Contrivance, as more or less of the Chains suspending the Buckets come to be wound off their respective Wheels *Y* and *Z*, this Weight gradually falls in as a Counter-balance, and so continues the Motion equable and easy in all its Parts.

THE Water wasted by this Machine, is not above the hundredth Part of what a Water-wheel will expend, to raise an equal Quantity. But where a Fall, proportionable to the intended Rise of Water, cannot be had, with a convenient Sewer to carry off the Waste-water over and above, this Device cannot be well put in Practice.

N.B. *The Iron Wheel-work or the Jack in this Draught, is represented something larger than its proper Proportion, for the sake of being distinct.*



J. Cole sculp.

FLUIDS *are sustained in the Air, without a COUNTER-PRESSURE from above.*

THE Service of the Atmosphere in the raising of Water being ascertain'd, it may not be amiss in the next Place to shew, that a Quantity of a Fluid so heavy as Water, will not sink therein, unless the Air have Liberty to press on the upper Surface thereof, as well as the nether; which may be prov'd by filling, suppose a Pint Mug, or a large Drinking-glass, to the Brim with Water, then covering it with a smooth flat Piece of Paper, and inverting it, the whole Body of the Fluid will remain therein supported; as in *Fig. 2. Plate 6.*

It will be granted, that if the Paper was put dry on such a Vessel empty, it would sink in the Air, and fall away even by its own Gravity; and if put on wet, 'twere to be doubted whether a very small Weight added thereto, would not separate it from the Glass, so inconsiderable would the Tenacity of the Water be in this Case. The Paper therefore cannot be supposed to support the incumbent Weight of Water; and the true Cause thereof must be this. The Bottom and Sides of the inverted glass Vessel being rigid, keep off the Pressure of the Air from the Fluid above, whereas it hath Liberty of Access, and freely acts thereon below: And that it does so, will in Part appear to an Observer by the Concavity

vity of the Paper underneath. Could the Air's Pressure in this Case be any how admitted thro' the Foot of the Vessel inverted, without doubt the whole Column would descend together. And the like would happen should the Paper be removed; but for a different Reason, *viz.* the large Column of Water in the Mug, being composed of many collateral ones, which being disposed as in a Bundle, rest on the Paper where-with the Vessel is covered, as on a common Base; and these being all equally dense, and equally fluid, are all retained, and continued of the same Length by the general and uniform Pressure of the Air against the Paper below; and so long as this continues, none of them getting the least Advantage over the rest, they are all sustained in a Body compact together. But when the Paper is removed, it being scarce possible to hold the Vessel so exactly level, but that some one or other of these smaller fluid Columns will become longer, consequently heavier than those adjacent, and over-balancing the rest will descend, and give the lighter Fluid, the Air, leave to rise into its Place, even to the Top of the Glass; the general Pressure whereof being there admitted, will soon cause the rest of them to move, and the whole Quantity will then descend, seemingly together.

AGAIN, should a Vessel be but Part filled with Water, the same Effect will follow to a certain Degree: For Instance, suppose we fill a long Glass one half with Water; cover it with Paper, and turn it down as before. Six Inches suppose of Water, endeavouring to descend, will by its Weight

Weight rarefy the Air in the Glafs above it, perhaps a fixtieth Part or more. The denser Air without will then overpoife the Air rarefy'd within; and therefore a certain Quantity of Water, equal to the Difference of the two Preflures, will in this Cafe be thereby buoyed up and supported. But the Air within the Glafs being dilated as aforefaid, the Water fufpended muft be expected to hang fomething below the Mouth of it, though not enough perhaps to overcome the Tenacity of the Water, and make it all defcend.

On the FOUNTAIN at COMMAND.

UPON this Principle acts the *Fountain at Command*, *Fig. 3. Plate 6.* The upper Part whereof, *A*, is hollow, having a Pipe foder'd therein, as *C*, continued nearly to the Top, on which, being thruft into a Wire Socket, it refts; and by which it may be charged with Water, when turned down, to any Height. In the under Part of *A*, at *a a*, are feveral fmall Tubes or Holes, thro' which this Water will, on the Admiffion of frefh Air thro' *C*, on Occafions iffue. The Bottom Part *B*, is hollow to receive the Water which thefe fhall difcharge thro' an Opening of a certain Bignefs, placed immediately under the Orifice of the middle Pipe *C*, the Area of which Aperture is fomething lefs in Content than that of all the fmall Holes at *a a* taken together. When therefore thefe all run, they will yield more Water than can by the other be received

ceived in any given Time. This will cause the Water to rise in the Bason, so as frequently to cover the End of *C*, and interrupt the successive Entrance of the Air, and consequently take off its Pressure from the Surface of the Water inclosed in *A*: Whereupon the Descent of the Fluid thro' *a a* will be discontinued, till such Time as the Water collected at Foot is run off, and the Passage for the Admission of fresh Air cleared: 'Twill then be repeated, stopping and running by Turns, as at the Word of Command, which may be easily given, by observing the Motion of the Fluid about the Foot of *C*.

On the DOUBLE FUNNEL.

IT is for the same Reason that the Juggler's Funnel *AB*, *Fig. 4. Plate 6.* is used to run or stop by Permission. .

THIS Machine is made of Tin doubled, and as it is to be first filled to the Brim with Water, stopping the End of the Pipe with the Finger, the Fluid will rise into the Vacancy or Hollow between the Plates, as in the greater Cavity of the Funnel equally. The Air in such Vacancy inclosed, being pushed by the rising Water thro' the Hole, ordinarily concealed under the Handle, which must be stopp'd when the Machine is full, and continued so till the Artist thinks fit to dissolve the Charm, and set the Waters confin'd at Liberty, which he can do by a single Touch of his Finger.

*On the AIR-PIPE, commonly called
the ANTIGUGLER.*

THIS Subject may not be dismissed, without considering the Use of the Antigugler, in the quiet decanting of Liquors liable to a Sediment. Having seen the Necessity of the Air's upper Pressure, to promote the easy and uniform Flux of Fluids from close Vessels, commonly called *Giving them Vent*; 'tis no Wonder that in decanting of Liquors, where this is wanting, there should happen a kind of Struggle between the grosser Fluids, endeavouring by their greater Gravity to issue forth, and the Air by its Repressure endeavouring to prevent it; whence such convulsive Motions in the Body of Liquors are produced, as often raise their Bottom, and make them foul. To prevent this Inconvenience (which, was it proper to make a Vent-hole in the Bottle, might soon be removed) the Antigugler was invented. This Machine is no more than a crooked Tube of Metal, so bent as easily to be introduced in the Neck of most Bottles. Its general Form is represented *Plate 6. Fig. 5.*

IN order to use this Instrument with Success, the Bottle containing the Liquor to be decanted is to be inclined a little to one Side. Let then a small Quantity of the Liquor, half a Spoonful perhaps, gently run off, to answer which, an adequate Quantity of Air will enter thro' the

the Neck with a kind of Glub, and take Place in the upper Part of the Bole. With your Forefinger then, in the Ring *C*, and your Thumb held close on the End of the Pipe *A*, introduce the Machine into the Neck of the Bottle, thrusting it quite thro' the Body of the Liquor, till the End *B* reaches, or is pretty near to the Bubble of Air before admitted. In doing whereof, the Liquor cannot enter, to obstruct the Passage of the Tube, being kept out by the Air inclosed, and by the Thumb therein confined. This done, on taking off your Thumb, an immediate Vent will be given to your Bottle, and the Liquor will continue to flow out steadily and unconvulsed, with much less Trouble than by the Syphon, and to equal Advantage: For a Current of Air, equal both in Weight, Force, and Quantity, to the Liquor decanted from the Bottle, will then successively enter thro' the Pipe, to maintain a just and peaceful Equilibrium between them.

*On the FLUX of FLUIDS in a
STREAM, both confined and not.*

WHEN Water is at Liberty to flow from the Surface of a Pool, or any other Head, thro' a Hole an Inch Square, kept just full, Monsieur MARRIOTE, who has been very exact in this kind of Experiment, informs us, that thirty cubick *Paris* Feet and a half, will be thereby discharged in an Hour's Time. That thro' a Hole two Inches below the Surface, and one Inch broad, eighty one cubick Feet

Feet will pass unforced as before. By one of like Breadth, and four Inches deep, two hundred and twenty-two cubick Feet and above a half will run off. By another of eight Inches deep, that five hundred and eighty-three cubick Feet and near a half will be discharged, &c. Quantities by no means, in any regular Proportion. And from the same Author we learn, that a Channel eighteen Inches deep, and one broad, will yield near one thousand nine hundred and sixty-six cubick Feet, almost three times as much as does one at but nine Inches or half the Depth, and sixty-four Times the Quantity given by a Hole one Inch square, in the same Time, next the Surface.

WHENCE it appears, that the Weight and Pressure of the incumbent Fluid above, augments the Efflux of Water below, and continues progressively to do so the deeper we go. And since this is the Case, where every Part of the confluent Pillar hath Liberty and free Scope to follow simply the Laws of Gravitation, it may well be expected, that when a Head of Water is kept up and confined, all the collateral Columns whereof are known to press equally according to their common Height, should it then be opened in divers Places below the Surface, the Expence of Water at each would be very different, thro' Apertures or Holes of the same Diameter. And this Expence is always found to be in a subduplicate Proportion to their Distances from the Surface: That is to say, the Hole that is four Feet below the Surface, shall yield twice the Water in the same Time as will the same Open-

ing at one Foot. One at nine Feet, shall give three times the Water of the first; and at sixteen Feet deep, the same shall supply four; and at twenty-five Feet, five times the Water in any given Time that may be had from a Hole made but one Foot beneath the Surface of the Head; and the contrary, inverting the Proposition. For Instance: I find in one Part of the Service, that *B* receives three times the Water that *A* does in another, thro' Pipes of equal Bore in equal Times; it follows then, that he lies nine Times lower with respect to the Reservoir, than *A*; and so of any other Proportion.

Now the Quantity of Water each may expect to receive, may be estimated sufficiently near, from the said Monsieur MARRIOTE's Experiments; who found, that the Expence of Water, issuing horizontally thro' a Quarter of an Inch Bore, thirteen Feet beneath the Head (*Paris* Measure) yielded just fourteen *Paris* Pints in a Minnte. On this Principle the following Table is calculated, which may serve to give an Idea of the Expence of Water made thro' vertical Apertures in any Service, not more than fifty-two Feet beneath the Reservoir, where extraordinary Friction and undue Hindrances are removed: Remembring only, that the Proportion of the *Paris* is to the *English* Foot, as 16 to 15 nearly; and that the *French* Pint is a very small Matter bigger than our Quart, for which proper Allowances are to be made in all Calculations of this Kind.

The TABLE.

PARIS FEET.	PARIS PINTS.
1	3,8829
5	8,6824
10	12,2770
13	14,0000
15	15,0383
20 or 4 times 5	17,3648 double that of 5 F.
25	19,4144
30	21,2675
35	22,9715
40 or 4 times 10	24,5540 twice that from 10 F.
45	26,0472
50	27,4560
52 or 4 times 13	28,0000 twice that from 13 F.

AND from the same Principle, the just Expence of Water for a greater or less Depth, at any Time, might be found according to Theory, by saying,

As 13 Paris Feet; the Height of the Reservoir on which the Experiment was made,

Is to 14 Paris Pints; the Quantity in a Minute yielded thro' a Quarter of an Inch Bore:

So is the Geometric Mean between the said 13 Feet and the Depth proposed; or the Square Root of their Product,

To the Expence of Water in like Time issuing thro' an equal Bore, at the Depth required.

IT may by the Way be here remarked, that on the Trial, the Quantity of effluent Water very often falls short of what might thus be expected from Theory; the Reason of which will be consider'd hereafter.

THE Proportion of Water that may be supply'd, in like Circumstances, that is, by equal Apertures or those of $\frac{1}{4}$ of an Inch Bore at any Depth below the Head, being however thus far determined, the Quantity to be received there for Service, will next be found to depend on the Bigness of the Bore, or the Section of the Pipe leading to the Cistern from the Main.

On the SIZE of PIPES of CONDUCT.

THE Capacities of Circles are always in Proportion to the Squares of their Diameters: So that if a certain Quantity of Water be supplied by a Bore a Quarter of an Inch in Diameter, in any Place, thro' one of half an Inch, four times, and by one of an Inch, sixteentimes, the Water will in the same Time be admitted.

AND to find in general what the Size of cylindric Pipes to supply Water on the same Level, in any given Proportion, ought to be, this Analogy may be used.

*As the known Quantity of Water supply'd by a Pipe of any certain Bore, in a given Time,
Is to the Square of the Diameter thereof:*

So

So is the Quantity of Water in an equal Time required,

To the Square of the Diameter of the Bore of the Pipe sought; in a direct Proportion.

FOR Instance: Suppose that by a Pipe of an Inch bore, I receive 120 Gallons of Water in the usual Time of Service, but as I want 300 Gallons on a Water-day, the Bore of my Pipe ought to be an Inch and $\frac{1}{16}$ to do this.

AGAIN: Suppose I have a Water-pipe two Inches in the Bore, which on Experiment supplies my Cistern in an Hour and a half; but wanting this to be done in half the Time, I would know what the Bore of the Pipe for this Purpose ought to be. I then say,

As 90 Minutes, the Time in which 'tis now done,

Is to 4, the Square of 2 Inches;

So is 45 Minutes, or half the Time,

To the Square Root of 8, or 2,828 Inches, the Diameter of the Pipe required; in a reciprocal Proportion.

AND by the same Rule, a Pipe 3,464 Inches in Diameter, will be found to do the same Service in a third of the Time, or thirty Minutes.

BOTH the Rules foregoing may be sufficiently confirm'd by Experiment. The first relating to the Expence of Water, issuing by equal Openings, to be in a subduplicate Proportion of

the Distance beneath the Head, by making Holes of the same Diameter in any perpendicular Pipe, kept always full of Water, at Distances in the Proportion propos'd, *Pag.* 81. The first suppose at three Inches beneath the Surface, the second at twelve, the third at twenty-seven, the fourth at forty-eight Inches, &c. and 'twill be found, that double the Water will be yielded by the second as will issue by the first in equal Times; thrice the Water by the third; and by the fourth, double the Water of the second, &c.

AND to prove the second Rule given, *viz.* that by an Opening of twice the Diameter, four Times the Discharge will be made at the same Level; in any Part of the Tree make such Openings, or for greater Exactness, have Slip-pipes, well bor'd in that or any other Proportion, to thrust into the Holes. Let these be stopp'd and unstopp'd at the same Instant; and the Measure of the Water issuing will sufficiently demonstrate them to be in Proportion as are the Squares of their Diameters, if nothing obstruct.

On FRICTION in WATER-WORKS.

THE Obstructions in Water-works commonly proceed from the Friction of the Fluid with the Pipes of Conveyance, and other Parts of the Apparatus, either from an undue Confinement in some Part or other, or from Flexure, that is, by a Change of the Line of its natural Direction to another, by a too acute or an improper Angle.

SINCE

SINCE the Circumferences of Circles are in a direct Proportion to their Diameters, the larger the Pipe of Conduct is, the less will the Friction always be. For Instance; the Circumference of a Circle whose Diameter is 2, is no more than twice as great as that whose Diameter is but 1; and its Surface being only double, there can be no more than twice the Friction of Parts from this, as from that; provided the Fluid move in both with equal Degrees of Velocity: Whereas the Area's or Sections of circular Pipes, are in a duplicate Proportion, or directly as the Squares of their Diameters. The Pipe then, which has 2 for its Diameter, has 4 for its Area; and consequently, with only double the Friction of the Pipe whose Diameter is 1, discharges four Times the Water in equal Times.

THAT there is a Disadvantage attending the Change of the Direction of a Fluid, appears from Experiment; since it has been found on Trial, that if fifteen Pints run from a Hole made in the Bottom of a Vessel kept constantly full of Water, in a given Time, there will issue but fourteen thro' an Opening of the same Size in a like Time, and in the same Level, spouting perpendicularly upwards, tho' each Hole had the same Height of Water constantly above it, and when the Work was done with the greatest Judgment, and the least Friction that could be. This Check proceeded no doubt from changing the Direction from the perpendicular Line of Gravitation, to another contrary to it, thereby occasioning probably several Reflections of the Fluid from Side to Side of the Bend, which must needs prove a

considerable Hindrance to the issuing Stream : Whereas had a Length of Pipe been affixed and added to the Bottom Hole, the Efflux of the Water thereby would be still greatly augmented ; because the longer a heavy Body continues to fall, the greater is its Acceleration downward.

Mr. MARRIOTE found, upon repeated Trials, that a cubick Foot of Water would run off thro' a Pipe of an Inch Bore six Foot long, in thirty-seven Seconds ; thro' a Pipe of equal Bore, and but three Foot long, it was discharged in forty-five Seconds ; and by the Hole only, without any Pipe at all, in ninety-five Seconds : Whence it appears, that a Length of Pipe added, does greatly promote the Acceleration of a falling Fluid.

SINCE the Efflux of Water thro' any Hole must be with the Celerity which a Body wou'd acquire in falling, from the Weight of the superincumbent Water, it is not difficult to determine *à priori* what the Velocity and Quantity of effluent Liquors ought to be : Yet in reality, as was hinted, there generally comes out less than the Theory requires ; the Odds being sometimes greater and sometimes smaller, depending doubtless on the Form of the Hole of the Cock, or thro' which the Water spouts ; that is, as these happen to be more or less properly adapted to the Figure or Shape of the effluent Vein of Water, naturally contracting itself into a much narrower Area than that of the emitting Perforation. But if that Passage or the Cock were so well fitted to the converging Motions of the streaming Fluid, as adequately

to embrace the contracting Vein in all its Parts, then the Quantity of Water and its Velocity passing thro' the narrowest Part of the Aperture, will answer pretty near to the Theory, as Sir ISAAC NEWTON has observed.

AN Experiment was accurately made by Dr. DESAGULIERS, of the running of Water horizontally thro' a Hole five eighths of an Inch in Diameter, the Centre whereof was just four Foot below the Surface of the Water in a Vessel kept always full. This Vein of Water so contracted itself, that at half an Inch Distance from the Hole, that is, where it seem'd thinnest, it all ran thro' a Hole of half an Inch Diameter made in a tin Plate. By afterwards weighing the whole Body of Water produced, and reducing it to a Cylinder of half an Inch Diameter, or something under, it appear'd, that the Velocity of the Water issuing, was the same as a Drop of Water wou'd have acquir'd in falling the Height of four Feet *in Vacuo*. In this Case therefore we are not to call the Hole, or Aperture, five, but four eighths of an Inch in Diameter; and that we may always consider as a Hole without Friction, with which the Theory will sufficiently correspond.

It must at the same Time however be confessed, that considering the great Difficulty there is in making Experiments of this kind with tolerable Accuracy, the Want of Excellency in a proper Apparatus for the Purpose, and the Nicety and Skill required in measuring the Breadth of the running

ning Vein, to which may be also added, the Length and Disposition of the Sides of the emitting Pipe, and all other Impediments to be consider'd, that it will not be improper to have an Eye at the same Time upon Experiment and Measure in Cases of this Kind, and not wholly to depend on any Tables or Calculations whatever; according to the Advice of the Marquis DE POLINI, that ingenious and truly accurate Author, in his *Treatise de Castellis*, Sect. 64.

On the ACCELERATION of FALLING BODIES, by GRAVITY.

THE Acceleration of Bodies falling in *Vacuo*, may be rightly represented by the odd Numbers, as they progressively rise. If in the first Second of Time, a heavy Body, freed from any Resistance of the Medium thro' which it ought to pass, will descend with the Velocity of sixteen Feet, and one tenth; for sake of Brevity, say, about one Rod; during the Space of the second Second, 'twill fall with the Velocity of three: So that at the End of the second Space of Time, it will be got downwards in all four Rods. By help of this Acceleration, continually promoted by the Power of Gravity, or Attraction toward the Earth, during the third Second, the Body will fall with the Velocity of five Rods; during the fourth with seven; the fifth with nine; and so on progressively till it reach the Center of Gravity, which with us is the Center of the Earth.

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THE ACTION of Gravity on falling Bodies, is easier to be conceived by Reflection than illustrated by Words; because we want Images wherewith the progressive Action of it can be well compared. Let us, however, suppose a Body like a Tennis-ball, wholly without Weight, and therefore not subject to the Law of Gravitation: Such a Body put in Motion, and meeting with no Impediment, will move, as all Matter inclines to do, in a streight Line, according to the Direction given it. Let us then suppose a Number of Men standing a Rod asunder, in a Row, with Rackets in their Hands. Let the first strike this Ball, giving it one Degree of Motion; 'twill therewith proceed on to the second: Let him also give it a Stroke; 'twill then go on with two Degrees of Motion to the third; who striking it also, will send it forward with three Degrees of Motion to the fourth; who communicates another Degree of Motion to it, and so forward. Or, which is the same thing in Effect, let one Man give it a Blow, then follow and strike it successively at the End of every Rod. 'Tis certain, the more Impulses are thus given by the Strokes of the Rackets, the greater will the Acceleration be; and a Body having no Weight will, in this Circumstance, thus proceed.

Now it cannot be supposed that Gravity acts, as the Case is here put, by Fits and Starts, and at the End only of every Second of Time; but incessantly, and at every Instant, from the very Beginning to the End of the Fall. Let us then suppose Gravity, or Weight, given to our Ball,
and

and that it is either Iron or Lead, and dropp'd from some Eminence. If at the End of the first Second of Time, when it has acquir'd the Velocity of one Rod, it should lose its Gravity, and cease to be heavy; it would thenceforward, meeting with no Impediment, proceed with the Velocity of one Rod in a Second continually. But as that cannot happen, and as the Impulse of Gravity is constantly acting thereon, it not only will, in the second Second, gather Power to go one Rod forward, as at first; but also acquire in the Interim an additional Force, precipitating it still onwards a Rod: As if the Racket should not only strike it, at the Beginning of the second Space of Time, but should make thereon a kind of a shoving Stroke, so as to send it on thenceforward with the Force of three. At Beginning of the third Second, let us imagine it to receive a new Impulse and Gravity, during the Interval, still acting, brings it to the fourth Second with the Velocity of five. In this Manner, an additional Impulse being obtained by the Weight still drawing, 'twill during every succeeding Second be accelerated by the Force of two progressively; which makes the Velocity by falling Bodies acquired, always to increase in the Ratio of the odd Numbers, *viz.* 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, &c.

HOWEVER difficult it may be to describe the Action of Gravity on falling Bodies, in Words; 'tis certain, that in Practice, and on Experiment, the abovesaid Rule is found to be critically true: The Space pass'd thro' by falling Bodies, where

no Obstruction is, in Fact being always in Proportion to the Squares of the Times passed over during their Descent. For Example ; one Rod passed by a heavy Body, in the first Second of Time, with three Rods passed in the second Second, make four Rods, equal to the Square of the Time, or two Seconds. Again, this four added to the five Rods, passed thro' in the third Second, make nine, equal to the Square of three. And nine added to seven Rods, passed in the fourth Second of Time, make sixteen, equal to the Square of four. To this add nine Rods, gone thro' in the fifth Second, and 'twill make twenty five, equal to the Square of five ; and so forward.

To measure therefore any Depth, 'twill in general be a very good Way to count the Seconds a heavy Body, or one not sensibly affected by the Resistance of the Air, is falling ; and the Square of those Seconds, multiplied by the known Space that a heavy Body falls thro' in one, will give the Answer in Feet, sufficiently near. For,

As 1, the Square of one Second,

Is to 16 Feet, the Descent in that Second :

So is the Square of any other Number of Seconds,

To the Space by a Body fallen thro' in the Time required.

FOR Instance ; I find by all Circumstances, that a Stone falls plumb into Water, 7 Seconds after 'twas delivered from the Hand: 'Twill then be 49 Times 16, or 784 Feet down to the Water.

Water. We ought indeed to allow about eleven hundred and fifty Feet, or three hundred and eighty-three Yards, in a Second, for the Return of Sound to the Ear, if the Object cannot be seen to plunge: But if that be done, such Allowance is not necessary; since the Progression of the Rays of Light is incomparably swifter than that of Sounds.

AND on the contrary; if the Height be known, by the same Rule may likewise be determined in what Time a heavy Body, let fall from the Top, will reach the Bottom. Let us, for Example, take *Salisbury Steeple*, said to be four hundred Feet high.

As 16 Feet, the Space passed in one Second of Time,

Is to the Square thereof, or 1:

So are 400 Feet, the given Space or Fall,

To 25, the Square of five Seconds, or the Time in which this Experiment might be made.

AND in order to discover what Space a falling Body may have passed thro' in any one particular Second of Time during its Fall, for Example, in the twelfth after the Delivery; the Difference between one hundred and forty-four the Square of the twelfth, and one hundred and twenty-one, the Square of the eleventh Second, the Time under Consideration, will determine it to be about twenty-three Rods.

AN Idea of this Matter may also be pretty well had from GALILEO's Method, delineated

Fig. 6. Plate 6. wherein the Intervals or Times of the Body's Fall, represented by the equal Parts $ABCDE$ in the Line AE , the Velocities wherewith they fall, are denoted by the equal Lines BF , CG , DH and EI , at right Angles therewith; and the Area of the triangular Spaces, all similar and equal, point out directly the Quantity of the Fall, or the Acceleration of the Body, in any particular Space of Time. For Instance; in the first Second, AB representing the Time, FB the Velocity arising from Gravity; the Triangle ABF compleated, will denote the Space gone thro' in that Time, or one Rod. If the Time be doubled, as AC , the Velocity will also be doubled, and then represented by CG . Compleat the Triangle ACG . and the first Space ABF , will be found four Times contained therein. If the Time be tripled, the Velocity will still bear the same Proportion, and then the Space passed thro' will be represented by the whole Triangle ADH , containing nine Spaces or Rods; and so on to the fourth Second, and forward.

SINCE falling Bodies are in this Manner accelerated, it may seem difficult perhaps to conceive how a perpendicular Pipe, fix'd at Bottom of a Vessel of Water should continue, during the Efflux, always full; which, strictly speaking, ought not to be so, on Account of this Acceleration, which ought to cause the Water to run out of the Pipe faster than it really should come in: Whence it might be apprehended,

hended, that in Time the Pipe might be empty before the Water was all out of the Vessel. To which we reply; that tho' all Bodies are by Gravity accelerated in their Fall, in the Proportion of the odd Numbers already mentioned; and must allow, that if two heavy Bodies, *A* and *B*, be let fall one Second after another, the first would get a Head of the other, nor would they keep at an equal Distance during their Descent. For if at the End of one Second, after *A* is let go, *B* should be delivered, the first will be proceeding at the Rate of 3, while the other is getting on but at the Rate of 1. During the third Second, *A* will be by Gravity urged on with the Force of 5, while *B* can have obtained the Celerity but of 3. So that if at the End of the first Second, they were but a Rod asunder, at the End of the second, they would be three Rods apart; five at the End of the third, seven at the End of the fourth, and so forward progressively. Yet it ought here to be consider'd, that the Water in our perpendicular Pipe, does not run into, and out of it, successively and by Starts, but evenly and continually. And tho' by the Acceleration of falling Bodies, their Velocity does increase, on which Account the Water in its Progress thro' the Pipe, if the Resistance of the Air and every other Impediment was away, might be allow'd to be a small Matter rarefy'd; yet as the Particles of Water contain'd in the descending Pillar, set forward one after another in Spaces of Time infinitely short, and being tenacious, adhering pretty well together, they appear as to Sense, to make an even Stream, and full in every

every Part. 'Tis therefore impossible, that so long as there is Water in the Vessel for a Supply, such Pipe should become void of Water; nor is the Objection any more than a Nicety.

IT may however here be remarked; that when the Pressure of the Fluid above the Hole of the Pipe, is so far abated as not wholly to fill it, the Evacuation will then be continued apparently in a spiral Figure. The like happens on pulling up the Plug of a Cistern; when the Water is almost run off, being resisted by the Air beneath, it falls of itself into a screw-like Motion, leaving a Hollow in the Middle, round which it seems to twist itself forward. Nor is it unlikely, but that the whole Column of Water in its Progress thro' the Pipe, even when fullest, may naturally incline always to move in this Manner, the better to overcome the Friction of the Fluid against the Sides. A very great Disposition to this kind of Motion may be observed by the Stream, as often as Liquors are poured leisurely from one Vessel to another: And indeed in all small Effluencies or Veins of running Water whatever, this Spinning in the Fluid is very remarkable.

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*The MOTION of PROJECTILES, nearly
in the PARABOLIC CURVE, demon-
strated.*

TO the Power of Gravity attracting heavy Bodies downward, in Combination with the impellent Force, by which they are obliged to follow a different Direction, it is owing, that Fluids, in the Way of *Jets-d'Eau*, and indeed all other Projectiles, move nearly in the parabolic Curve; which a Spout of Water, or rather Mercury, will at any Time describe, if the Jet have any Degree of Elevation: And if it be made horizontally, only a semi-parabolic Figure will be produced. The Draught of the one is exhibited *Fig. 7.* and that of the other *Fig. 8. Plate 6.* The Reason why projected Bodies endeavour to move in that Manner, will come next under Consideration.

'TIS a famous Proposition in Mechanics, That when a Body is impelled by two different Forces at the same Time, not directly in the same Line, that it will not proceed strictly in either of their Directions; but somewhere between both, *viz.* in the Diagonal of a Parallelogram compounded of both. For Instance: Let a heavy spherical Body at *A*, *Fig. 9. Plate 6.* be struck with a Spring, or receive some other impulsive Force, in the Direction *AB*, it would thereupon incline to move from *A* to *B*; or let a like Im-

pulse

pulse be given it along the Line AC , the same will happen: But let both Springs strike it together, and give it different Directions as before, it will then roll absolutely in neither, but along the Diagonal Line AD , thereby intimating to us the certain Direction of that Force which is thus compounded of the other two.

To prove this by Experiment: Take a Ball, fasten to it two Threads; in a Table bore two Holes, as in the Diagram at C and B , thro' which put the Ends of the Threads, to which let equal Weights be hung; bring the Ball to the Point A . In this Case should either of the Weight, be suffered to draw singly, no doubt our Ball will follow in the Line of either Direction indifferently from A : But let them both act thereon together, it will then move in the Diagonal, and incline to pass from A towards D , tho' from the Nature of the Experiment it can only reach half Way.

AFTER this, let the impulsive Forces be put unequal, the like will happen, and the Diagonal of a Parallelogram, whose contiguous and opposite Sides are proportionable to the different Weights at Bottom apply'd, will truly point out the Path or Line of Direction, in which the Body thus impelled will incline to move. For Instance: Let the Force intimated by the Line AB continue the same as before, but diminish that represented by AC one half; the Line denoting the new Force must be diminished in the same Proportion, and the Pa-

parallelogram will then be constructed on the Lines AB and AE , the half of AC ; the Diagonal whereof will be the Line AF . In this Case also bring the Ball again to A , and quitting it, suffer these two Forces to act thereon together, you'll find the Ball will move along the Diagonal of this new Parallelogram, as before it did along that of the other, so long as the impulsive Forces continue to act in Conjunction; which will be, as before, to about half Way of the Line AF .

THIS holds universally true, and may therefore properly be applied, in accounting for the Movement of Spouts of Water, and all other projected Bodies nearly in the Direction of the Parabola; which is generated between that Force by which the Body is impelled forward continually decreasing, and the Power of Gravitation continually increasing.

FOR Instance: Let us suppose that a Cannon planted at the Top of the Pike of *Teneriff*, or any other sharp Hill, was, with a small Charge of Powder, to shoot a Bullet horizontally, which, had it no Gravitation towards the Earth, that is, was it without Weight, would fly off as all Matter inclines to do, having a horizontal Direction given it, or one different from that of Gravity, in a Tangent Line to the Earth; just as does a Stone from the Circle wherein 'twould whirl'd round by the Sling. And was the Resistance of the Air and all other Mediums removed, it would always maintain the same Velocity.

locity with which it left the Muzzle of the Piece. But as neither of these can happen, in the present State of Things, let us consider what will follow. First, the Resistance of the Medium thro' which the Ball passes, will every Moment obstruct, and at length become equal to the Impulse by the Powder given; which alone will in time reduce it to a State of perfect Rest. Secondly, the Power of Gravity continually acting thereon, will at the same time conspire to bring it out of the Line of the Fire, and cause it to tend downward, in the Proportion of the Acceleration of falling Bodies, already mentioned.

LET us suppose, that in the first Second after the Discharge, when the Impulse given is strongest, the Bullet will pass forward, at the Rate of ten Rods. Gravity, as soon as the Explosion is made, puts in its Claim, and tho' it shall be then but weak, and the other strong, yet 'twill be able to bring it down toward the Earth by the Space of one Rod; or in *Fig. 7. Plate 6.* from *A* to *B*. During the next Second, suppose it retarded somewhat, by beating thro' a Quantity of Air, so that it can get forward in this Second but at the rate of nine Rods. Gravity, never silent, but always acting, will bring it downward mean while with the Velocity of three: Of consequence therefore, 'twill move along the Diagonal of the two acting Forces, as described in the Draught from *B* to *C*. The third Second, 'twill, being still retarded as before, proceed but with Velocity of eight Rods. Gravity by that Time will demand a Descent

of five Rods; so that the Place of the Projectile will then be found at *D*. The following Second, for the same Reason, it gets on but at the Rate of seven Rods perhaps; Gravity in the mean Time causing a Descent of seven Rods, the Ball's Place will then be at *E*. The fifth Second, 'twill keep on at the rate suppose of six Rods; Gravity that while making it descend nine, and the Ball moving along the Diagonal of a Parallelogram whose Sides are proportionable to the Strength of the two Forces, by that Time will bring it as far as *F*. And thus one of them gaining, and the other losing Power continually, it will reach perhaps the Earth, having describ'd a Curve pretty near a Semi-parabola,

THE Representation of the Parabola in all its Varieties, may by a Jet of Quick-silver, receiving all the different Degrees of Inclination, contained in a Quadrant or Quarter-circle, be at any Time observed. And here it may be remarked, that the utmost Range, or the greatest Projection that can be made of a Ball, is always obtained when the Elevation of the Tube or Piece is about forty-five Degrees, or the half of a Right-angle, above the Horizon, as in *Fig. 8. Plate 6*. Wherein the greatest Distance a Bomb can be thrown to from the Mortar at *C*, is supposed to be represented in that Degree of Elevation. Whereas should it be raised above that Angle; for Instance, to fifty Degrees, it will not throw it near so far; and should it be lower'd as much, or down to forty Degrees, the Consequence will

will be the same. And thus, by two different Inclinations of the projecting Tube, a Projectile may be made to fall on the same spot of Ground; traversing however very different Tracts of Air to get thither.

It ought here however to be remarked, that were Bodies near our Earth to be projected in an unresisting Medium, according to the Doctrine of GALILEO, their Motion wou'd be perform'd in the Parabola exactly. But as all our Observations must needs be made on Bodies moving in the Air, the Curve they really move in falls considerably short of that Line, which they wou'd otherwise have described; and especially toward the End of their Motion, when the projectile Force by Reason of the Resistance of the Air is much impaired. Nor is this Deviation inconsiderable, even tho' the projected Body be of Lead or Iron, especially if they be thrown far: But the Odds is still greater, if the projected Body be so light as Water.

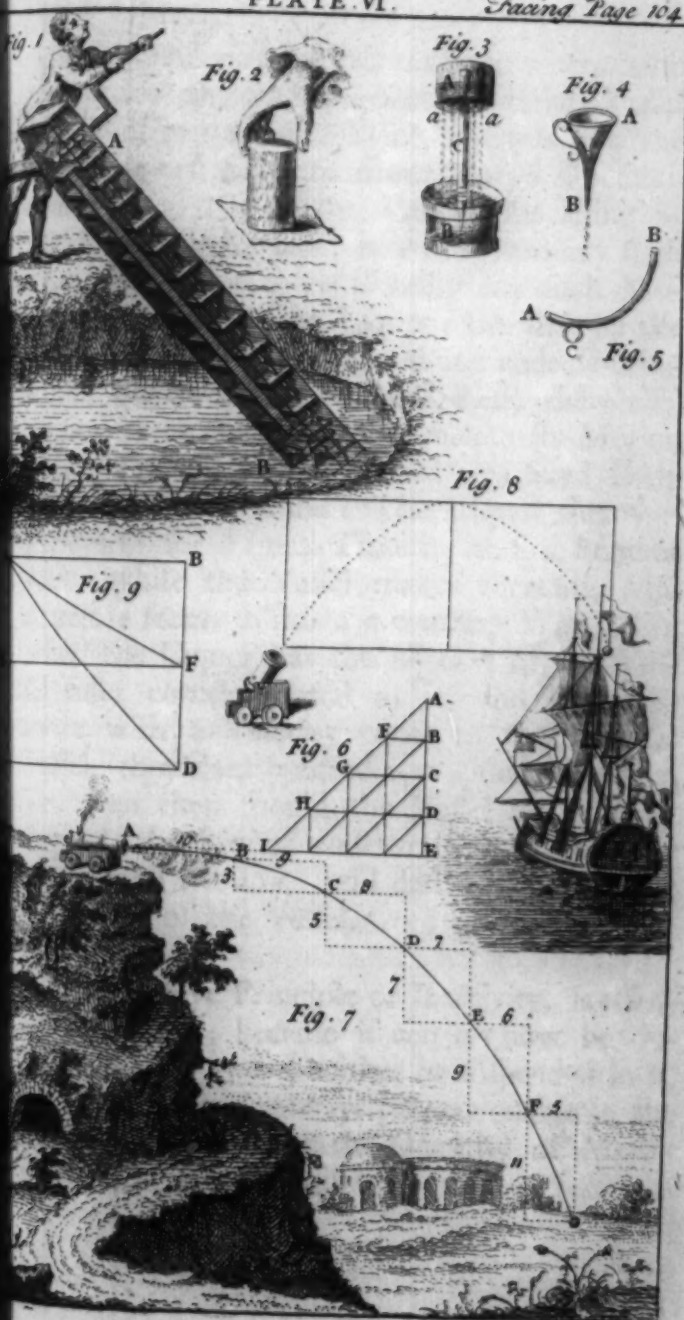
Sir IAAC NEWTON demonstrates, that the Motion of Projectiles in Air is rather perform'd in a Curve of the hyperbolic kind; and he accordingly found that a horizontal *Jet-d'Eau*, which should have gone to the Distance of forty Inches in a Parabola, upon Trial reach'd only to thirty-seven; the Resistance of the Air taking off a thirteenth Part of its projectile Force. In Dr. GRAVESAND's Experiments, instead of thirty-one Inches and a half, it only reach'd twenty-nine and a half; not much different in

Proportion from the former. And even in the Experiments which Mr. REAUMUR made with a Body so dense as Quicksilver, the Heights and Distances, especially in great Elevations, were something less than the Theory of Parabolas required, merely from the Resistance of the Air; the Quantity of which Resistance is now to be considered,

On the RESISTANCE of FLUIDS, to BODIES moving therein.

THERE are two Kinds of Resistance in Fluids: The one is from the Viscidity, Tenacity, or Cohesion of their Parts; the other from the Inactivity, or what Sir ISAAC NEWTON calls the *Vis Inertiæ* of Matter.

THE Resistance of the latter is that Force by which every Body endeavours to continue in the State 'tis in, whether of Rest or Motion. That of the former is a Resistance, produced over and above that of the *Vis Inertiæ*, by the Spissitude or Viscidity of some Fluids. For Example; was a Body dropp'd into melted Honey, supposing the Honey in that Circumstance to be a perfect Fluid, the Resistance it meets with, when moved therein, will be according to the *Vis Inertiæ* only: But when the Parts of the Honey, by cooling become stiff, the Difference of the two Resistances will then be that of the Tenacity.



THE *Vis Inertia* of Matter is no where more conspicuous, than in the sudden Motion of a Vessel full of Water along a Plane, upon which the Liquor at first seems to move with a Direction contrary to that of the Vessel; for rising against the hinder Side, it will commonly dash over. Not that there is really any such Motion impressed on the Liquor; but that by the *Vis Inertia* of Matter, the Water endeavouring still to continue in a State of Rest, the Vessel cannot in an Instant communicate its Motion to it; it not being a consistent or a fixed Body like itself, but a Fluid: The Liquor therefore perseveres for a small Time in its first State of Rest, while the Vessel makes forward, and therefore seems to move a contrary Way. But when the Liquor has the Motion of the Vessel fully communicated to it, and begins to move with a Velocity equal to that of the Vessel, they then proceed very quietly together. Yet even then should the Vessel be suddenly stopp'd, the Liquor endeavouring to continue its acquired Motion, will dash again over the other Side of the Vessel.

THIS passive Principle or Inactivity, is essential to Matter; because it can no how be depriv'd of it. It can neither be suspended in it, nor abated; but is always proportionable to the Density of Bodies, or the Quantity of Matter they respectively contain.

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THE Resistance from Tenacity in Fluids, if it be not always uniform, is directly according to the Degree of Velocity in the moving Body only; because the Viscidity of the Matter will be barely separated to make Way for its Motion. And this yielding of the Parts is always the same, whether the Motion be swifter or slower: whereas the Resistance of the *Vis Inertiae* is always as the Squares of the Velocity of the moving Body; that is to say, suppose one Body moves with three Degrees of Velocity, and another but with two; the different Resistances they will meet with in that Case, will not be as 3 to 2, as is that of the Tenacity, but as 9 to 4. Or again; suppose a Body to move first with one, and then with two Degrees of Motion, the Difference will there be as 1 to 4; because the Body having twice as much Motion, it must strike twice as many Parts, and doing it with double the Velocity, must strike them twice as hard, and consequently push them twice as far. Just as if I should give ten Shillings to-day to ten Men, and to-morrow should give twice the Number of Shillings a-piece to double the Number of Men; 'tis plain, my Distribution to-morrow will be four times what it was to-day.

THIS again may be demonstrated by Experiment, thus: Take four or more smooth flat Bodies, suppose boxen Draught-men; let these represent as many Particles of any fluid Matter. Lay them on a smooth Surface, two and two a-breast, pretty close together; pass any Thing

that

that is smooth and hard gently through them, they will be just separated thereby, and pushed sideways barely to once the Breadth of the moving Body. Join them again, and let the Body pass thro' them with twice the former Velocity, they will not only be parted as before, but will be struck off laterally also, to twice the Breadth of the moving Body. Increase the Velocity still, and the Parts moved thereby and displaced, will evidently appear to be according to the Square of the Degrees of the Celerity wherewith this is done.

UPON this Account 'tis plain the Resistance of Fluids to moving Bodies may on some Occasions be very considerable; and when the Velocity of the Projectile is very great, it may equal even the Resistance of a solid or fixed Body. For Instance; let a Cloth be spread suppose a Yard under Water; with a moderate Charge of Powder, fire a Bullet at it, 'twill probably pierce it: Whereas should you double the Charge, and repeat the Experiment, the Ball will be beaten flat, and not reach the Cloth perhaps before the Force of the Powder is spent.

In Vacuo all Bodies fall equally fast; a Cork for Instance and a Bullet, a Feather and a Piece of Gold, all lodge themselves exactly together. The true Quantity of this Fall, in the first Second after Delivery, is experimentally found as was said to be 16,1 Feet *English*; tho' in our former Calculations, the Word Rod was used to prevent Multiplicity of Words, and Confusion from broken

broken Numbers. Was there a Medium for these Bodies to pass thro', they would none of them fall so far in the same Time; and the less ponderous Bodies would be affected by its Resistance most: So that the Cork might soon cease to move with an accelerate, and afterwards continue to fall with an equable Motion in the Air; which the Feather would likewise do, but sooner still.

THE Resistance of the ordinary Fluids, such as the Air, Water and Mercury, is observed to be chiefly owing to that of their *Vis Inertia*, and very little to their Tenacity: So that the Density of Fluids being known, their Resistance is easily calculated. Thus Water resists about eight hundred and fifty, and Mercury about eleven thousand nine hundred Times more than Air. And it has been found by causing Pendulums to oscillate or swing in those Fluids, that the Motion lost by their Resistance, was justly proportionable to their Densities, or the Quantities of Matter in them severally contained.

FOR the Confirmation hereof, we must refer to Sir ISAAC NEWTON's Experiments: Who filling a Vessel of a considerable Length with Water, let fall in it spherical Bodies, of different specifick Gravities, and then calculating how far they would fall in that Medium, regarding its Density only, and rejecting the Tenacity, he found the Experiment answer'd to it. And in Company of Dr. DESAGULIERS, he let fall Bodies of like Form, from the upper Gallery of
St.

St. Paul's Cupola, two hundred and seventy-two Feet from the Ground, and found the same Thing to happen also in the Air. Whence it sufficiently appears, that the Air has no sensible Tenacity; much less then can it have either Attraction or Cohesion of Parts.

Of J E T S - D ' E A U.

WE have seen that Fluids led in Pipes, will always rise to the Level of the Reservoir whence they are supplied; the rising Column being pushed forward, and raised by another equally heavy, at the same Time endeavouring to descend. And a like Effect might be expected from Jets of Water, thus impell'd, did not Friction against the Sides of the Machines, and the Resistance of the Air, both lateral and perpendicular, generally prove an Abatement, and prevent its rising so high as the Head.

WHERE Jets are executed in the best Manner, and the Friction spoken of is as much as possibly removed, the Impediment of the Air only, thro' which they needs must beat in their Rise, will cause them, according to Experiment, to fall short of the Height of the Reservoirs, in the following Proportions, *viz.*

110 *The Motion of FLUIDS,*

J E T. RESERVOIR.

FEET.	FEET. INCH.
5	5 : 1
10	10 : 4
15	15 : 9
20	21 : 4
25	27 : 1
30	33 : 0
35	39 : 1
40	45 : 4
45	51 : 9
50	58 : 4
55	65 : 1
60	72 : 0
65	79 : 1
70	86 : 4
75	93 : 9
80	101 : 4
85	109 : 1
90	117 : 0
95	125 : 1
100	133 : 4

WHENCE in general it may be observed ;

That so often as a five Foot Jet (to be taken in these Matters as a Standard)

Shall be contained in the Height of any Jet proposed :

By so many Inches multiplied into themselves, or squared,

The Surface of the Water in the Reservatory which supplies it, ought to exceed that Jet in Height.

THUS

NATURAL *and* ARTIFICIAL. III

THUS to obtain a Jet of thirty Foot, which contains five Foot six Times, the Reservoir ought to be thirty-six Inches, or a Yard higher; and a Jet of sixty Foot may be had from a Head higher by four Times that Difference, 144 Inches, or four Yards. So that *Jets done in the best Manner fall short of the Heights of their Reservoirs, in a kind of subduplicate Ratio of the Heights to which they rise.*

THIS great Disproportion in the Rise of Jets must in general be owing to the Resistance of the Air they are made to move thro'; which has been shewn to be in Proportion to the Squares of their Celerities respectively: Nor can the Acceleration of the falling Water in the Pipe, or the Retardment of the rising Stream by the Action of Gravity, be concerned at all in it; since these are probably adequate, and counter-balance each other every where in the same Level.

THE Air's Resistance being thus considerable, 'twill always be found necessary to increase the Bore of the Adjutage or Spouting-pipe, with the Height of the Reservoir: For if it be too small, the rising Stream will want sufficient Weight and Power to divide the Air; which being densest near the Earth, a small Stream of Water, endeavouring to mount to a great Height, will be dashed against it with so great Violence, as to fall away in a Mist and be wholly lost. And it may be observed, that the weightier any Body is, the greater Force it will have when in Motion: Since an Ounce Ball

112 *The Motion of FLUIDS,*

fir'd from a Musquet, will go much farther, and do greater Execution, than will an equal Weight of Shot; and these again may be projected farther than so much Lead rasp'd into Powder and fir'd off. A Charge of Water fir'd from a Pistol wou'd scarce wet a Paper at the Distance of six Feet. Accordingly, should a Cask of Water be any where pierc'd with Holes, of two, four, six, eight and twelve Lines over, all in the same Level, the larger Bore will always be found to throw the Water farthest.

It may be of Use here to add Mr. MARIOTE's Proportions of the Bores of the Adjutages and Pipes of Conduct, who was very conversant in these Things, and hath written very well on this Subject.

N. B. *The French divide their Inch into twelve equal Parts, which they call Lines.*

<i>Heights of Reservoirs.</i>	<i>Diameters of fit Adjutages.</i>	<i>Diameter of the Pipes of Conduct.</i>
FEET.	LINES.	LINES.
5	3, 4, 5, or 6	22
10	4, 5, or 6 - -	25 INCHES.
15	5, or 6 - -	27, or $2\frac{1}{4}$
20	6, or half an Inch	30, or $2\frac{1}{2}$
25	Ditto - - -	33, or $2\frac{3}{4}$
30	Ditto - - -	36, or 3
40	7, or 8 - - -	51, or $4\frac{1}{4}$
50	8, or 10 - -	65, or $5\frac{1}{2}$
60	10, or 12 -	72, or 6
80	12, or 14 -	84, or 7
100	12, 14, or 15	96, or 8

HENCE

HENCE it may be remarked, that there is a certain and fit Proportion to be observed between the Adjutage whereby the Jet is delivered, and the Pipe conducting it from the Head. In general, *About five times the Diameter of the Adjutage for Jets under half an Inch, and six or seven Times for all above, will size the Pipes of Conduct pretty well*: Not but 'twill always be an Error on the right Side, to have them rather larger than in strictness they ought to be, that the Jet may always be freely supplied with Water, and in due Time.

FOR a like Reason, if there be Occasion for a Cock to be placed in any Part of the Pipe of Conduct, particular Care must be taken, that it should be there bigger in Proportion, that the Water-way may not be pinched; but that the Cavity be left at least equal to the Bore of the rest of the Pipe.

THE Expence of Water made by Jets thrown to any Altitude, may be pretty well collected from what was said under the Article of the Flux of streaming Fluids from Openings beneath their Head, *Page 83*, and the following, *viz.* That from equal Bores, it would always be in a subduplicate Proportion of their Heights. All necessary to be added thereto is, That if thro' any Hindrance or Deficiency in the Conduct-work, a Jet should happen not to rise so high as might be expected from the Regulation in this Section laid down *Page 110*, the Expence of Water on that Occasion ought not to be computed from the Height of the Reservatory, but

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from

from the actual Rise of the Jet. For Instance: Suppose a Reservoir of thirty-three Feet, which ought to play a Jet of thirty Feet, plays but one of twenty, which a Reservoir of twenty-one Feet four Inches, done in a good Manner, would also do; in this Case regard being had to the Size of the Adjutage, the Expence of Water can possibly be no greater than what a twenty Feet Jet might be expected to make.

THE Bore of an Adjutage cannot be too smooth or true. Those that are cylindrical are best; those that are bored conical worse, because of the Reflections of the Water from the inclined Sides of the Machine, which in the Hurry of the issuing Stream will in them unavoidably be made.

To conclude this Subject, let us a little attend to the Construction of a very pretty portable Fountain, that being once charged with Water, and inverted, will play a Jet nearly as high as the Reservoir, till the Fluid is exhausted; and then turned up on the other End, the same Thing will happen, and a real *Clepsydra*, or Water-clock, be thereby formed.

THIS Device represented *Plate 7. Fig. 1.* consists of two hollow Vessels, *A* and *B*, communicating with each other only by the recurved Tubes *C* and *D*; at the Ends of which, *E* and *F*, are plac'd small Adjutages to direct the Jet. *G* and *H* are two open Tubes, solder'd into the Bottom of the Basons belonging to *A* and *B* thro

thro' which the Water flows in, and fills those Vessels to a certain Height, that is, according to their Length. They by their Disposition also prevent the Return of Water the same Way, when the Machine is turned upside down.

On the SPECIFICK GRAVITY of
BODIES.

ARISTOTLE's Notion of the Elements was, That the Earth and Water were positively heavy; Fire positively light; and Air indifferent as to either. His Followers therefore affirm, That the Ascent of Bodies is owing to their positive Levity, as that of Flame and Smoke, for Instance. But in this they are mistaken: For Bodies are only relatively light or heavy, according as they are compared with others of a different Kind. So that Flame or Smoke ascend not because they are really light; but because they are buoyed up by the Air, which is denser, and therefore in its Nature heavier than they: For Flame in *Vacuo* will soon subside; and Smoke, when the fuliginous Parts thereof become heavier than the Medium round them, will visibly descend. Thus, Oil or Wine do not swim on Water because of their own Levity; but because Water is the heavier Fluid, and sinks in them. In Air most Bodies sink, because it is very light; in Water not so many, it being far more dense, and in Mercury scarce any may be totally immers'd, from the like Cause. Nor is there any greater Reason that Cork should be termed light, because 'twill

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swim

swim in Water ; than that Iron should be esteemed so, because 'twill swim in Mercury.

IN general therefore, *One Body is said to be specifically heavier or denser than another, when it contains more Matter, or a greater Degree of Weight, under the same, or an equal Bulk ; or an equal Degree of Weight, within less Space or Compass.* For Instance ; a cubick Inch of Gold weighs ten Ounces Troy, an equal Quantity of Lead hardly six, of common Water, something better than half an Ounce ; so that Gold is about nineteen, and Lead about eleven times denser, and therefore specifically heavier than Water : And thus of the rest.

SPECIFICK Gravity then is appropriate, or the Gravity peculiar to any Body, whereby it may be distinguished from Bodies of a different Kind. 'Tis sometimes, and not improperly, called *relative or comparative Gravity*, to distinguish it from *absolute or positive Gravity* ; which last always increases in Proportion to the Bulk of the Body weigh'd directly, the other not. Absolutely consider'd, a Pound of one Thing is as heavy as a Pound of another, without regard to what their specifick Gravities are : Thus a Pound of Feathers, Cork, or Sponge, absolutely weighs as much as does a Pound of Lead ; but with regard to their relative Gravities, or Bulk for Bulk, they are very different.

A Body specifically heavier than a Fluid, will sink therein, because it weighs more than an equal

equal Quantity of the Fluid by it displaced; and whose Room it takes up: So that the imaginary Surface immediately under the Body, being there more press'd than by the Water in any other Part, it therefore yields, and lets it pass thro'. But a Body specifically lighter than a Fluid; will always rise therein; because it presses less on the imaginary Surface beneath it, than the Fluid in whose Place it is substituted would have done; and the collateral Columns of the Fluid adjacent, by their proper Weight, contribute to its Rise.

Was there any necessity of proving this by Experiment, it might thus be done: Take a small glass Bolt-head, which, was it solid and of a Lump, wou'd be near three times heavier than Water; but being hollow, and full of Air only, 'twill emerge and swim. This may be so nicely filled with Water, by the Stem, that at Top of a Jar it may be made to swim; in the Middle it may remain at a poise; and put beyond that, or lower, it may sink.

This will be brought about by the Spring of the Air included therein; which being a compressible Body, will either contract or dilate itself according to the Degree of Pressure 'tis under. Toward the upper Part of the Jar 'twill be press'd but little more than the Atmosphere; toward the Middle, by the Atmosphere and some Inches perhaps of Water; and at the Bottom, by more Water still. In the first Case, the Air in the Machine cannot be so much press'd as in the second; in the second, not so much as the last: Whence,

as the Pressure comes to be increased, more Water will be gradually thrust into it, as the Mouth of the Machine is unstopp'd, making the whole specifically more heavy, and so will produce the forementioned Effect very visibly, when tried on a Machine that is small.

UPON the same Principle it is, that glass Images are made to rise or sink in a long Jar of Water at the Word of Command. These have commonly a Hole left in their lower Parts, thro' which, by only sucking out the Air, having a little Water at the same time in one's Mouth, they may be so far charg'd therewith, as will cause them to swim erect, at Top of the Jar. Let this be afterward stopp'd with a good yielding Cork, or cover'd with a Leather or Bladder, well tied over the Mouth, and a Pressure of the Hand occasionally applied thereon, will cause them to sink; and on Abatement of that Pressure, they will rise again at Pleasure; or by an equal steady Degree of Pressure, they may be stopp'd, or seem to be suspended, in any Part of the fluid Column.

THIS accidental Pressure is, in Effect, equivalent to the lengthening out the Pillar of Water, in the last Experiment: For, by a greater Degree of Pressure applied, the Air being condensed in the Image, more Water will be thrust into its Cavity, which the Air, in its Restitution, will thrust back when that Pressure is withdrawn. Both these Experiments are represented under the *Pneumatics*, Fig. 18, Plate 8,

By the way, it may here be remarked, that there are very few, if any, Animals of themselves specifically heavier than common Water. The real Substances indeed of both Animals and Vegetables frequently are so; and the floating of either is generally owing to the Cells or Receptacles in them interspersed, which in the one are fill'd with Air or Oil, in the other with Air or Refin, which being all lighter, will swim in Water. If then Flesh and Bones are of themselves somewhat heavier, the Fluids and the Fat are somewhat lighter; to which if we add the large Quantity of Air in these every where included, as on Cupping, &c. evidently appears, they will be found together to make a Mass specifically a good deal lighter than a comparative Bulk of common Water. Besides, as the Bulk of the Body is capable of being increased by distending the Chest in Inspiration, a good Quantity of Air may be taken into it, and this is a farther Advantage to the floating Animal.

It has been tried by a fat Man of ordinary Size, what Weight he could bring up from the Bottom of the *Thames*, so as to have the Top of his Head just appear above Water. When his Breast was full of Air, he was found to rise with thirteen Pounds of Lead, without striking out in the least, and two Ounces more would have kept him under: But when his Breast was not thus distended, he could bring up only eleven Pounds in that manner.

It would be therefore difficult to conceive how People, not incumber'd with their Clothes, should be so often drowned as they are against their Wills; and, unless by struggling unartfully, and admitting Water by their Mouths, they were suffocated, the Thing would seem impossible. One unavoidable Disadvantage indeed they do lie under, and that is from the sudden Contraction of the warm Air within the Body, on its first Immersion in cold Water; to supply the Place of which, they are apt to distend their Lungs immediately, and are in a manner forced to gasp for Breath, when meeting with a Fluid too gross for Respiration, they fall a Sacrifice to their Fears, for want of that Presence of Mind which the Brutes, whose Apprehensions of the Danger being less, are evidently Masters of. This, like other Prejudices, we should endeavour to conquer while we are young, before they are too deep rooted with us, and predominate.

ALL Bodies floating on Fluids, may also be justly compar'd with them; and whenever a Body lighter than a Fluid does float thereon, a Quantity of that Fluid, in Bigness equal to the immers'd Part of the Body, is precisely equal in Weight to the absolute Weight of the whole Body. A Man of War, for Instance, carrying a hundred and twenty Guns, with all its Stores, Rigging, and Appointments, weighs not a Jot more than does the very Quantity of Water which it thrusts away and displaces, and which would otherwise have occupied the Room of that very ponderous Machine. This Water
being

being of a certain and determined Weight, wou'd naturally have press'd on the imaginary Surface of the Fluid, just beneath, with its proper Gravity : But as that Part of the Ship which is under Water, falls into the Place, substituting thereon an equal Weight, the same Pressure, and no more, is still sustain'd by the said Surface. And were it otherwise, the Water, being fluid, wou'd continue to yield and move till the Equilibrium was fully made; which always is observed to happen whenever Vessels of this kind come to be laden deeper.

THE Motion of the Waves in a Gale of Wind, whereby an unequal Degree of Pressure is accidentally thrown on the smooth Surface of the Sea, also evidently shews us this. But to prove it farther by Experiment ; Take a Stick of Wood specifically lighter than Water, and counterpoise it in a Pair of good Scales with Water : Immerse the Stick gently in a full Jar ; Part of the Water will be thrust out thereby, and run over : Take out the Stick, and the Water in the Scale will be found again exactly to replenish the Jar. Which sufficiently proves, what was before intimated ; *That a Quantity of a Fluid, equal to the immers'd Part of a Body floating in that Fluid, will in Weight equal the Weight of the whole Body.*

HENCE a tolerable Judgment may be form'd of the different Specifick Gravity of all such Bodies lighter than Water, as will not be damaged by Immersion therein. For Instance ; The Density and Weight of the several Sorts of
Wood,

Wood, may this Way be compar'd, by putting Sticks of the same Length, equally seasoned or dry, and of the same Form and Bigness throughout, or prismatick from one End to the other ('tis no matter whether with regard to each other their Form or the Diameters of their Base be the same) into a narrow Jar of Water, like that in *Fig. 1. Pl. 1.* the better to keep them up on End, noting how far, when gently let down, they will sink in the said Fluid. And accordingly, a Piece of *English Oak* a Foot long, will be found to sink about eighty, Beech seventy-five, some sorts of Mahogeny sixty-nine Hundredths of a Foot: So that the Density of Oak may this Way be found to be to that of Beech, as 80 to 75, or 16 to 15; and to that of Mahogeny, as 80 to 69, nearly as 8 to 7. And by Consequence, their several Weights, and perhaps their Strength and Degrees of Service, might pretty well be judg'd of, by inverting the Terms; that is to say, seventy-five Feet of Mahogeny are equivalent in Strength to sixty-nine of Beech; and eighty of Beech to seventy-five of Oak. Their Duration indeed, depending on their Texture and particular Constitution, will be another Consideration.

On the HYDROMETER, *or* WATER-
POISE.

THE relative or specifick Gravity of Fluids to each other, may this Way in general also be tolerably well discover'd, viz. by the Immersion of an Instrument called the Hydrometer,

or

or Water-poise, in them one after another. This Machine is usually made of Glass, Ivory, or some Substance not very porous, or apt to imbibe much Liquor. It consists of a Bole of any reasonable Size, but the larger the better, as *A*, *Fig. 2. Plate 7.* and a long small Stem, as *B*. The Bole is commonly loaded with a little Small-shot or Mercury, to cause it to swim upright; and its Weight is generally adapted to the Liquors 'tis intended to prove. The Neck is mark'd with equal Divisions, commonly put on the Out-side. The large Part or Bole of this Machine is supposed to be compar'd with an equal Quantity of the Fluid in which 'tis immers'd. The Stem, as 'tis small, happening to be more or less immers'd, makes no great Difference. The heavier the Liquor, the more buoyant it is found to this Machine; and the lighter, the less will it be supported therein. In Vinegar or Pickle, for Instance, 'twill not sink near so deep as in Spring-water: This again, having more Salts in it than Pond or River Water, wherein they have had more Time to subside (which they constantly do, forming thence Slime or Mud proper for manuring of Land) will bear it up better than they. In Wine this Instrument will be less supported; and in spirituous Liquors made more light or subtiliz'd by Distillation, it will sink more or less according to their Quality or Degrees of Strength.

THE lightest Waters are the most wholesome, tho' they may perhaps be generally less palatable than those that are heavier. Water that has been
fil-

filtrated thro' a thick Fannel, or percolated thro' the Pores of a loose and sandy Stone, will be very light, clear and good. But Water distill'd, tho' it may be very light, yet wanting a due Mixture of Salts, will be both insipid and unwholesome. SIR ISAAC NEWTON'S Definition of Water is, *That it is a fluid Salt, volatile, and void of all Savour or Taste.*

SUCH Wines as have a natural Sugar in them, and are therefore more viscid and ponderous, as Canaries, and what are usually call'd the rich Wines, ought not to be taken too liberally: They are too nutritive alone, and ought to be well diluted with Water; and such will always be found very buoyant to the Water-poise. The lightest Wines, that is, the lightest in the Balance, are generally the most spirituous, therefore worse to digest or be overcome by the *Vita* of Animals. Witness Champaign, Tokay, &c. which of themselves are too strong and noxious, if drunk alone in great Quantities; but if mix'd with Water, in the antient Way, so making a Fluid specifically heavier are safe; being brought down thereby to the Condition of weaker Wines.

AND for the same Reason, Distill'd Liquors, having too great a Degree of intense Heat in them, can never be fit for common Drinking alone. These Things being mixed with the Blood, and other animal Juices, are rather apt to thicken than render or keep them fluid. The publick Discouraging the common Excesses
of

of this Sort, would therefore doubtless be attended with very happy Consequences, and particularly with regard to the Health of those who shall be thereby reclaimed.

As to Punch : The Mixture of the Acid and Sugar dissolved in Water, may possibly have been taken at first from the diluted Oxymel of the ancient *Greeks*, or more probably from the Sherbet now in use among many of the *Asiatics*; and the Brandy, Rum, Arrack, &c. are added to give it a vinous Strength, agreeable to the Taste and Appetite, or perhaps the Wants, of northern Stomachs. In this Mixture the Fluency of the Spirit is pretty well corrected by the Viscidity of the Sugar; its Levity by the Gravity of the Acid, and the poignant Strength of all these Ingredients being lower'd by a sufficient Quantity of Water, it becomes an artificial Wine, both wholesome and pleasant; and 'tis therefore a favourite Liquor with the *English*.

THE specifick Gravities of Red-wine and Water will appear to be different, if a small glass Bolt-head, as *A*, *Fig. 3. Plate 7.* full of common Water, be inverted into a Glass of Claret, *B*. The Water being heavier, will visibly descend, and take Place at Bottom of the Glass; and the Wine being more light, will rise through the Body of Water by degrees, for just the same Reason as Smoke does in serene Air, and take its Place at the Top of the Bolt-head, till at length all the Wine shall have

taken Possession of that Machine, and all the Water of the other; as from their different Gravities they are inclined to do.

IT is a common Experiment, to pour Red-wine upon a Quantity of Water in a Glass with a steady Hand; putting a Bit of thin Bread or Paper first afloat in the Water, to ease the Fall of the Wine into the heavier Fluid, that the Section, where the two Liquors part unmix'd, may be better observed. Then with a Pipe either the one or the other of them may indifferently be drawn off first.

WHEN Water and this colour'd Wine however are heedlessly jumbled together, and have their Parts intangled as it were one among another with a Shock, they then cannot so easily be separated again, their Tenacity in great measure preventing it; they therefore remain thenceforward incorporated together, and as it were one homogeneous Fluid. However, as the Wine and Water thus mixed, make a Body still lighter than Water alone, if the Bolt-head abovenam'd, full of common Water, be again inverted into this Mixture, it will appear to rise therein as the Wine did at first, but not so briskly.

*Clar. B. The Water being heavier, will vi-
sibly descend, and take Place at Bottom of the
Glass; and the Wine being lighter will
float on the Body of Water above it, for
the same Reason as Smoke does in Air.
And take its Place at the Top of the Bolt-
head, till the length of the Wine shall have
been taken*

The

A
Cylind
low
Water

The PRINCIPLES, on which the HYDROSTATICAL BALANCE acts, demonstrated.

HAVING before prov'd, That the whole Weight of a Body specifically lighter than Water, is equal to the Weight of a Quantity of Water the same in Bulk to the immers'd Part of that Body; it comes next to be consider'd, *That all Bodies specifically heavier than Water, lose as much of their absolute Weight, in Water, as a Quantity of Water in Bulk equal to themselves shall weigh.*

To prove this Proposition experimentally; Take a Cylinder of solid Lead, exactly fitted to, and filling a hollow Cylinder of Brass; suspend the Lead at one Arm of a Balance; counterpoise it with Weights at the other, of which let the hollow Cylinder, fill'd with Water, be a Part. Immerse the Lead, suspended as it is, in a Jar of Water held in the Hand, not suffering it to touch either the Bottom or the Sides, and Weight will soon appear to be lost; which, on emptying the hollow Cylinder on the other Side of its Water, will appear to be immediately restored.

As a farther Evidence of this, let the solid Cylinder be suspended as before. Put the hollow one in the Scale on the same Side, void of Water, and counterpoise them justly. Immerse the

the Lead in a Jar of Water, as before, and the Weight lost thereby, on filling the hollow Cylinder before said with Water, will be replac'd.

AGAIN; *The Weight lost by any Body, on Immersion, will always be communicated to the Fluid wherein 'tis put.* To prove which, weigh a Jar of Water, and let the hollow Cylinder before-mentioned empty, be a Part of the Counterpoise. Let then the Lead, held by a String, be so immersed that it may neither touch the Bottom or Sides of the Jar; and the Increase of Weight found, will be again exactly counterpoised by filling the hollow Cylinder in the opposite Scale with Water.

NOW to account rationally for the Loss of Weight on the Immersion of the suspended Lead, it must be considered, That the Solid will then take up a Space in the Fluid, which would otherwise have been fill'd by a Portion of Water in Magnitude equal thereto; which Fluid would also have been every way buoyed up, and sustain'd in its proper Place, by the Parts of the Fluid adjacent; the Efforts whereof, upon putting in the Lead, are then transfer'd to and act against the Sides of the solid Matter, thus substituted, in order to support the same.

AND with regard to the additional Weight, or that acquired by the Fluid in which the Lead is immers'd, it must be observed, That on such Immersion, the Water is made to rise in the Jar in a just Proportion to the Bulk

of

of the Body immers'd, which then being substituted in the Place of so much Water, may well be consider'd as a like Bulk of Water added; and therefore must be expected to press the Scale as much as an equal Quantity of Water added would have done.

KING *Charles* the second, who encouraged, and indeed incorporated the Royal Society, would sometimes come and sit among them as President. At one of those Times, 'tis said, His Majesty diverted himself with enquiring; Why a Fish of a Pound Weight, being put into a Pail of Water, before justly counterbalanced in a Scale, was found not to augment the Weight of the Pail, so long as he supported himself therein, on his Fins? After Deliberation and some Debate, on a Proposition coming from such a Hand, One of the Members got up and told His Majesty; he doubted the Fact. The King merrily told him, so did he. Neither can it be doubted but that the Pail was really a Pound heavier, upon putting in the Fish. Had the Subject indeed been an inanimate Mass heavier than Water, so long as it was in the Article of Sinking, the Weight introduced, as if it had been held, suspended or lowered down by a String, would, as in the last mentioned Case, have been only that of a Quantity of Water equal in Dimensions to the immersed Body; I say, during that Interval: But so soon as it should have reached, and came to rest on the Bottom of the Vessel, the Increase found would doubtless have been that of the Body's absolute Weight.

K

As

As Bodies specifically heavier than Water, when immersed therein, lose of their absolute Weight taken in the Air, what an equal Quantity of Water in Air wou'd actually weigh; by consequence, *The Difference of the Weight of any such Body, taken first in Air, and afterwards in Water, will always be the just Weight of a Quantity of Water, equal in Bulk and Dimensions to those of the Body under Consideration, and will be at all Times fairly comparable with it; which being the Principle whereon the Experiments on the Hydrostatical Balance chiefly depend, requires a very particular Regard.*

THIS famous Proposition was first found by ARCHIMEDES, on the following Occasion. HIERO, King of Sicily, ordered the Workman a certain Quantity of Gold, to make the Crown Royal. It was indeed well designed and finely embellished; but the Artist it seems had made free with some of his Majesty's Gold, and had substituted in its Room an equal Quantity of Silver. On Delivery of the Work, a Suspicion of Mal-practice arose; the Crown was ordered to be survey'd, and the Thing refer'd to ARCHIMEDES, as a proper Judge of the Case, with Instructions however by no means to deface the Workmanship. It lay long before the said Referee, and the Maker thought himself pretty secure of his Perquisite. It happened however one Day, as the Philosopher was stepping into a Bath, that he took Notice the Water rose in the Bath in Proportion to the Part of his Body immersed.

immersed. From this Accident he received a Hint, wherewith he was so transported, that he jumped out of the Bath, and ran naked about the Streets of *Syracuse*, crying in a wild Manner, *I have found it ! I have found it !*

In consequence of this Speculation, he made two Masses, of the just Weight of the Crown ; one of Gold, the other of Silver. These he severally let down carefully into a Vessel of Water, wherein the Rise of the Fluid might easily be determined by Measure. Being of different specifick Gravities, they were consequently of different Magnitudes, and on Immersion took up the Room of different Quantities of Water ; by comparing whereof with their absolute Gravities in the Air, he became fully Master of the Relation, in Point of Weight, each of these Metals had to Water, and consequently to each other. He then served the Crown in like Manner, and by comparing his Observations, he at length detected the Cheat, and fairly assigned the Quantities of Gold and Silver contained in the Crown respectively.

On the Use of the HYDROSTATICAL
BALANCE.

THE Hydrostatick Balance, in order to find the specifick Gravity of Fluids, or how they differ from each other in Point of Density, has commonly a Lump of solid Glass, shaped like a Heart, a kind of Wedge, the

more easily to cleave and separate the Parts of those Fluids in which it shall be occasionally immersed. Now this being made of Matter not liable to be injured by any Liquor, and of Weight sufficient to sink in most, is convenient for the purpose, and is represented as in Use by *A, Fig. 4. Plate 7.* This Machine has a fixed Counterpoise for the other End of the Beam, as *B*, which, when the Glass is pois'd in rain or river Water, will keep the Balance-beam just level, whether it be put at the Top, the Middle, or at the Bottom of the Jar.

Now all such Liquors as are specifically heavier, that is, more buoyant than common Water, will require Weight to be added on the Side of the immersed Glass, to restore the Equilibrium: And such as are less so, or lighter than common Water, will require Weight to be added to the Counterpoise, to bring the Beam, which ought to be singularly good and true, to a horizontal Position.

In comparing of two Liquors, in order to find simply whether of them is the heavier, 'tis of no great Concern to know what the Bulk or solid Content of our Essay-bubble *A* is. Because the Grains on either Side added, to bring the Beam again to a Level, will sufficiently determine how much a Quantity of them equal to the Bulk of the Bubble, differs from rain or river Water, to which the Machine is commonly adjusted; which is somewhat more of Satisfaction than from the Hydrometer can be

be had. But how much the Density of the one exceeds that of the other, or generally in what Proportion, cannot be known till the Weight of our glass Machine, both in Air and Water, and consequently the Weight of a Quantity of the Fluid under Consideration, in Bulk equal thereto, with which it is generally compar'd, be first adjusted and found.

It may here be remarked, that the Beam of the hydrostatical Balance can't be well too light, if it be but equal to its Office, without yielding or springing. The Way to prove whether it be true or not, is, when you have found any exact Equilibrium by it, to change both Weight and Scales together, end for end; and then, if no Alteration appears, 'tis perfectly well executed; otherwise not.

A square Piece of Paper, weighing but one Grain, may without Difficulty be divided by Measure into two and thirty Parts of a Grain; and if you desire your Beam should be affected by the Weight of a few of these, the rest of your Apparatus must be very light also; lest the Weight laid on the Point of Support, should make it too sluggish to move so free and finely as it properly ought to do.

SUPPOSE then the Weight of our Essay-bubble *A*, when taken in the Water, is one hundred and eighty-two, and in the Air two hundred and six Grains; the Difference, or twenty-four Grains, is then the just Weight of a

Quantity of Water equal in Bulk and Dimensions thereto: Which being known, may be received as a general Standard whereby to estimate the specifick Gravity of Liquors by such Machine. For Example; warm a Jar of Water pretty well, it will be thereby rarefied, and rendered specifically more light, and of consequence the Bubble, before adjusted to that Liquor cold, will on Immersion sink therein. And by adding Weight on the other Side, we may easily learn how much 'tis thereby become specifically lighter than a like Quantity of Water cold; viz. by deducting the Weight found on Experiment necessary to restore the Equilibrium, let us suppose three Grains from twenty-four; so that the specifick Gravity of the cold Water will be found to be to that of the hot, as 24 to 21, or 8 to 7.

FOR Experiment's sake, suppose a second Trial to be made the same Way, on a Fluid denser than common Water; as suppose strong Ash-lees, replete with a lixivial Salt, or Tunbridge-water, mixed with chalybate Matter, in which Case we are to add the Difference found on Immersion of the Essay-bubble, suppose four Grains to twenty-four; the specifick Gravity hereof will then be rightly signified by the Number 28, and an equal Quantity of those Liquors will be to common cold Water, as 28 to 24, or 7 to 6; and to an equal Quantity of the Water before warmed, as 28 to 21, or 4 to 3; and thus of any other.

FOR as Things equal to a Third, are certainly so to each other; so, by a Parity of Reason, Things differing from a Third in a known Proportion, also differ from each other in a known Proportion. As an Instance; Let *X* on Experiment be found three Ounces heavier than *Y*, known to weigh ten Ounces, and on Trial let *Z* be two Ounces lighter, 'twill follow, that *X* weighs thirteen of the equal Parts, of which *Z* weighs but eight: And that they relatively are as 13 to 8.

THE specifick Weight of equal Quantities of different Liquors might indeed be also found, by filling a small Phial, of known Dimensions and Capacity with them successively; which ought to be first exactly tared or counterpoised on the opposite Side. Their several Weights then taken by a nice Pair of Scales, and noted down, may afterwards be compared together tolerably well. And this was the Method the great Mr. BOYLE made Use of in these Enquiries: But in point of Dexterity and Cleanliness it falls short of the Machine here recommended.

IN like manner might also the specifick Gravities of solid Bodies heavier than Water be found, was it practicable to reduce them by any Means to some certain or determinate Dimensions, as to the Size of a cubick Inch, or the like; But that being not only laborious, tedious and expensive, but also inconvenient and much less exact; the Beauty of the hydrostatick

Balance will therefore appear in assigning their comparative Gravities, be their Figures never so various or irregular, with very great Truth, Ease, and Expedition.

FOR the weighing of Solids specifically heavier, or which sink in Water, hydrostatically, this Instrument is provided with a small glass Bucket, marked *C*, *Fig. 4. Plate 7.* which in the Air is exactly counterpoised by *B*; and in Water, by adding the small Weight *D* on the Bucket-side at *E*, to counterbalance the Buoyancy of the Water on the Bucket immers'd. By this Machine Fragments of such Bodies may be weighed indifferently either in Water or the Air; both which, in these Experiments, are always carefully to be distinctly done; noting their several Weights.

THE Difference of their Weights thus taken in Air and Water, as has been said, will be precisely that of a comparative Bulk of Water equal to the Magnitude of the Bodies immers'd. For Instance; a Solid, which in the Air weighs an Ounce, or 480 Grains, may counterpoise perhaps only three hundred and twenty Grains in Water; the Difference of which, or one hundred and sixty Grains, has already been proved, *Page 130.* to be the Weight of a Quantity of Water equal to the Body under Consideration in Bulk.

To find then the relative Weight, or the Proportion that such a Body bears to Water, the

the Rule is : To inquire how often the Weight of an equal Quantity of Water, discovered as above, may be found in the absolute Weight of the same Body, taken in the Air ; which in the last Example will turn out as 3 to 1.

IN order then to compare two solid Bodies of different specifick Gravities hydrostatically, as suppose Flint-glass and Magnet ; take Fragments thereof, no matter how various in Weight, or how different in Form. In the Bucket C, weigh them severally, first in Air, then in Water. But previous to the latter, Care must be taken to wet both the Bodies and the Bucket very well, that the Air, which is apt to adhere to Solids, and especially to lodge and be retained in their Pores, may be first extricated thence ; otherwise the Bodies will be thereby more buoyed up than they ought, and the Experiment therefore imperfectly made.

It may be observed by the by, that if thro' the different Density of Waters, either from Cold or otherwise, our Bucket shou'd at any Time happen to be a small matter either too ponderous or too light, this should be brought to Truth and adjusted before the Operation ; either by adding Weight to the lighter Side, not to be brought into the succeeding Calculation, or by adding something spirituous, if the Fluid be too dense, or a little Salt, if it prove too rare, till the Balance is well settled and brought to its first Adjustment. In Water then the before said Fragment

138 *The Motion of* FLUIDS,

ment of Glas will perhaps fetch up but an hundred and twenty Grains, and the Magnet but seventy-nine; these severally taken from what they weighed in Air, an hundred and seventy-one Grains, and an hundred and two, will leave, for Example, fifty-one and twenty-three; the respective Weights of their comparative Bulks of Water: It thence appears, that Glas is to Water, as 171 to 51, or as $3\frac{1}{3}$ to 1; and Magnet as 102 to 23, or as $4\frac{1}{3}$ to 1; and by Reduction of the Fractions equivalent, viz. $\frac{171}{51}$ and $\frac{102}{23}$ by cross Multiplication, it will be found, that of consequence Glas is to Magnet specifically, in whole Numbers, as 3933 to 5202, or nearly as 10 to 13; in a reciprocal Proportion.

Once more: There are two irregular Pieces of Ore from different Pits to be examin'd, and hydrostatically compar'd. The absolute Weight of *A* in Air, is 12 Ounces, *B* the other 14 $\frac{1}{2}$. In Water *A* is counterpoiz'd by 7 Ounces, *B* by 9. The Relation of the first to Water is as 7 to 5, of the second as 29 to 11. These reduced as above turn out as 77 to 145, nearly as 11 to 20.

THE Truth of these Essays will appear, by trying the Experiment on two or more distinct Pieces of the self-same Metal, or Matter, which however different in Magnitude, will be found nevertheless to be of the same specifick Weight, by the Method now proposed, if accurately performed. For Instance, cut a Copper Half-penny into two unequal Portions, of which suppose *M* appears

appears in Air to weigh 104 $\frac{1}{2}$ Grains, *N* but 40. In Water *M* 94. *N* 36. These reduced make the specific Gravities of the two Fragments as 840 to 836, which as the Numbers are high, is a Proof sufficiently near,

AND in this Manner are to be treated all other Subjects that will sink in Water, and not be damaged by the Experiment, whereby their Goodness in great measure may be often known: Such as Metals of all kinds; and Fossils, as Ores, Stones, Gems and Things of like Sort. This Method is of singular Service in discovering the Difference between Bodies of the same Denomination and Kind; for the specifick Gravity of such as excel being known, those inferior in Weight may be presumed to be inferior in Value and Goodness: At least, counterfeit Money may by this Method always be certainly known from true.

THE *Africans* are said to be so dextrous at this kind of Cheat, and gild so artfully, that their bad Money will abide the Touch, and their Gilding so strong as even follow the Shears, if the Piece be cut through. But tho' Money of a baser Metal may very much resemble Gold, bear the Touch-stone, and even weigh as much in the Air; yet will it never abide the Test of the hydrostatick Balance: For, as it must necessarily be made of coarser Metal, or Matter less compact and more porous, it will always be
more

more buoyed up in Water than genuine Gold in the like Circumstance would be.

By the same Method also, more exactly than by Measurement or any other Way, may be found the Cubic Content of any Solid, be it in Figure never so oblique or irregular. For, since two hundred and fifty-three Grains are found experimentally to be the Weight of a cubic Inch of Water; if a Groce of Tobacco-pipes, for Instance, were proposed as the Subject to be measured, and these should weigh, suppose twelve Ounces Troy, less in Water than in the Air, the Analogy will then be:

As 253 Grains of Water,

Are to 1 Cubick Inch:

So are 5760 Grains, the Weight of a Piece of Water adequate to the Bulk of the Body under Consideration,

To the Cubick Inches they contain, that is 23 nearly of burnt Clay.

Mr. WARD, in his *Young Mathematician's Guide*, gives the following Table of the specific Gravities; which being sufficient for common Practice, will here be not improperly inserted: By help whereof either the Magnitude or the Solid Content of any Thing specified therein, be it in Shape never so irregular or uncouth, may be found by the following Proportion, from its absolute Weight in Air only, viz.

As

As the tabular Number, according to the Subject, under Consideration.

Is to one Cubical Inch :

So is the absolute Weight of a Piece of wrought Plate, suppose, or other Matter consider'd.

To the solid Inches contained therein.

So that a Piece of wrought Plate, weighing 100 Ounces in the Scale, will turn out in Cubic Measure just 18 Inches. And a Marble Figure which weighs 120 Pounds will be found to want about 504 Cubic Inches of two Feet solid.

The

The T·A·B·L·E.

<i>The Cubick Inch of</i>	<i>Ounces Troy.</i>	<i>Ounces Avoird.</i>
Fine Gold - -	10,3592	11,3656
Standard ditto -	9,9626	10,9304
Quicksilver - -	7,3844	8,1017
Lead - - -	5,9840	6,5539
Fine Silver - -	5,8500	6,4183
Standard ditto -	5,5567	6,0965
Rose Copper - -	4,7471	5,2083
Plate Brass - -	4,4042	4,8321
Cast Brass - -	4,2724	4,6303
Steel - - -	4,1421	4,5445
Common Iron - -	4,0313	4,4230
Block Tin - -	3,8615	4,2366
Fine Marble - -	1,4294	1,5688
Common Glass	1,3608	1,4930
Alabaster - -	0,9884	1,0844
Dry Ivory - -	0,9621	1,0555
Dry Box - -	0,5432	0,5960
Sea Water - -	0,5427	0,5949
Common Water	0,5274	0,5787
Red Wine - -	0,5237	0,5746
Proof Spirits - -	0,4892	0,5368
Dry Oak - -	0,4890	0,5365
Linseed Oil - -	0,4916	0,5393
Oil-Olive - -	0,4815	0,5283

HENCE

HENCE we may observe, that Standard, or Guinea-gold, is as 9962 ; Standard Silver, as 5556 ; Cast Brass, as 4272 ; and Lead, as 5984, to common Water, which is about five hundred and twenty-seven of those Parts : So that being weighed therein, Gold should lose about a nineteenth, Silver little more than a tenth, Brass about an eighth, and Lead an eleventh of its Weight in Air. And if an hundred and twenty-nine Grains of each of these, the Weight of an unworn Guinea, be severally weighed in Water, the Gold will, on Experiment, turn out an hundred and twenty-two Grains ; the Silver about an hundred and fifteen Grains ; the Brass, which takes up more than twice the Bulk of Gold, an hundred and thirteen Grains ; and the Lead about an hundred and seventeen Grains : And if on the Essay they be not so, they are either naught, or different from what they ought to be.

HAD Capt. DAMPIER known this Method of determining the genuine Value of Metals, he had perhaps ventur'd to traffick with the Indians at the *Bashee* Island, for some of their Yellow Rings; which he says in his *Voyages* he had no great Encouragement to do, not being able to determine whether they were Gold or not.

SUCH

SUCH Bodies as will dissolve, or be damaged in Water, may be weighed in Oil of Turpentine, in which no Salts, Vitriols, or acid Sublimates, will melt, proceeding as with Water; considering only, that two hundred and twenty one Grains are a solid Inch of this Fluid.

To conclude this Subject : The Equilibrium of Bodies in the gross Air, if they be very different in Magnitude or Dimensions, will not continue in *Vacuo* ; because when two Bodies compared are unequal in Bulk, the greater taking up a greater Space, and protruding more Air from its Place, will be more buoyed up thereby than the other ; and when this Support comes to be withdrawn from both, the bigger must of course preponderate.

THERE are therefore fitting Seasons when Gold or Jewels may, strictly speaking, be bought or sold to most Advantage. If Gold be weighed against Lead ; that, as has been said, takes up but half the Room of this ; if against Brass which is lighter, and therefore still more bulky for its Weight, the Gold will of consequence be less buoyed up by the ambient Fluid, than the Weights wherewith it is compared. And, from the exactest Equilibrium of this Sort that might be made, was the Air to be withdrawn, the Weights would certainly preponderate.

Now, from the Alterations on the Barometer, we know the Air is capable of being on Occasions about a tenth heavier at one Time than another. Whenever it is most dense, it will of course be the most buoyant; and the contrary when it is more rare. If the things compared be specifically of the same Weight, they will be no doubt equally affected by any Alteration therein; when they are otherwise, a Difference will appear. If it be in your Choice therefore when to buy Gold, do it always when the Air is lightest, or in foul Weather; and if you can chuse when to part with it, let it be in fair Weather, when the Air is the most buoyant, and has the greatest Weight or Density.

BUT for Jewels take the contrary Method, they being nearly of the same specifick Weight with Chrystal, are to the Brass, against which they are usually weighed, about as 1 to 3, or according to the late Observations of the ingenious *Mr. Ellicot*, F.R.S. the Diamond is to cast Brass more exactly as 7 to 16. It will be therefore best to purchase them, and indeed all other light Commodities, when the Air is most buoyant, and to sell them when it is least so.

AND for a like Reason, the Dealer's Weights ought always to be made of the purest Metal, which being never so porous as the coarse, will reduce their Size; and 'tis allowed, that in Traffick the Advantages ought in Justice to lie on the Side of the Buyer.

L

UPON

UPON this Principle some have contrived an Instrument called the *Manometer*; which is no more than a nice Balance-beam, having a hollow Globe or Glas hung in Freedom at one of its Arms, and a Counterpoise of Metal added, when the Air is in a middle Way, at the other, with Intention to discover thereby the Rarity or Density of the Air. Whenever the Air became more buoyant, the Globe, being larger in Bulk, and consequently more supported than the Weight, would rise; and the contrary, when it came to be more rare. The Balance-cock, on a circular graduated Scale, was made partly to point out this Variation. But as this Machine can shew nothing more than what the *Barometer* in a much better Manner will do, it is enough to have mentioned it.



P N E U



PNEUMATICKS.



NEUMATICKS, a Sister-science of the HYDROSTATICKS, treats of the Nature and Properties of the Air, its Motions and Effects, in the same manner as the other does of those of Water and the grosser Fluids. It is commonly received among us for the *Doctrine of the Air*, or the Laws whereby it is condens'd, rarefy'd, gravitates, and the like.

The PROPERTIES of the AIR described.

THE Air is a thin fluid Mass of Matter, which hangs about, and revolves along with the Globe of the Earth in its diurnal Motion on its own Axis, and attends it on its annual Journey round the Sun. Let the Body of the Earth be represented by a Peach, the Air will be apply signify'd by the Down growing on its Surface.

THE whole Body of the Air, together with the Smoke, Exhalations and Particles of a different Kind floating in it, are in general called the *Atmosphere*.

THAT the Air is a Body, appears from its excluding other Bodies from the Place where it is. For Instance ; if we turn the Mouth of an empty glass Jar down into another full of Water, but little Water will get Admittance into the smaller Vessel ; and that only from the Compressure of the Air, by the Weight of Water endeavouring to enter, and the Air will possess the rest of the Room.

THAT the Air is a thin and yielding Fluid, whose Parts easily glide, and are moved one among another, is not denied by any. It was proved *Page 108*, to be without Tenacity, much less can it have any Attraction or Cohesion of Parts, which its Compressibility and Elasticity also sufficiently evidence.

THE Particles of the Air are indeed so fine, that they escape the Notice of our Senses ; they are not ordinarily to be perceived either by the Touch or the Sight : But yet when a Quantity of it shall be thrust together, as in a tight forcing Syringe, stopp'd at the End, the Resistance against the Piston is such, that if the Materials do not give way, no Power whatever will bring that Piston down. Thus by Force, may Air be squeezed together, or compressed ; and in pushing down our Piston, it may be observed, we seem to work against a very strong Spring ; which is one very sensible Instance also of the Elasticity or Spring of the Air.

THAT

THAT it is elastick, or endowed with an admirable Spring, appears also in Part by its constant Endeavour to maintain an equal Degree of Density in all its Parts; and by its immediately falling into Motion to make good all Deficiencies whenever they casually happen therein.

THAT it is heavy, appears by its Pressure on all Bodies expos'd thereto; and especially by its counterbalancing and sustaining all the grosser Fluids in elevated Pipes to a certain Degree.

THE Weight of the Air was proved by an Experiment propos'd *Page* 12. whereby a Quart of Air, of the common Degree of Density, near the Earth, will be generally found to weigh about twenty Grains *Troy*. To corroborate which, Air of the common Degree of Density, may in such a Vessel be still more condensed by the Injection of other Air from a forcing Syringe, upon which a considerable Increase of Weight will be found. And thus is the Gravity of the Air, not suspected by the Antients, become incontestable with us.

THE World is indebted to GALILEO for this notable Discovery. He found by Experiments, that Water might be rais'd by the common Pump to a certain Height, and no farther: Whereas had Nature abhor'd a Vacuum, as the Philosophers then thought, it might have

been raised indefinitely, as far as a Vacuum could be made. But this not appearing on the Trial to be so, he happily thought of the Counter-balance of the Air's Pressure, which Hint TORICELLIUS, BORELLI and later Philosophers, the *English* especially, have since pursued and very much improved upon.

THESE Gentlemen considering, that since the Weight of a Column of Air from the Earth to the Limits of the Atmosphere, was found equal to a Pillar of Water of like Dimensions, about thirty-five Feet in Height, and that as Mercury was fourteen times heavier than Water, 'twas probable one fourteenth Part of thirty-five Feet of Mercury would in like manner be an Equipoise thereto. Accordingly they took several Tubes of Glass, hermetically sealed or closed at one End, filled them with Mercury, and then inverting their nether End into a Cistern of the same, found that Part of the fluid Pillar, when held perpendicular, still flowed out, and that the other Part remained standing, as they expected it would, much about the same Height in all. This being noted on the Glass, and divers Alterations in the Height of the Mercury frequently appearing, after a long Series of Observations, it is at length agreed, That the Pressure of the Atmosphere, when least in very foul and stormy Weather, is much about equal to the Weight of twenty-eight Inches of Mercury; and in fine and serene Weather, that it will support about thirty-one Inches of that Fluid: Between which Extrems, all the Changes that

that happen in the Weight of the Air near the Surface of the Earth, are generally found to be. And to these Experiments is owing the Invention of the Barometer, or Weather-Glass; which, being well made, is a very curious Balance for determining from time to time the general Alterations in the Weight of the Air, and consequently is of great Use in foreshewing often what Weather may be expected.

On the BAROMETER.

THE most simple, and indeed one of the best Barometers, is this but now described, and is what any Person may himself make, having a clean glass Tube, closed at Top, more than thirty-one Inches long, and of any convenient Diameter; but the larger the better, that the Attraction of Cohesion between the Fluid and the Glass may be no considerable Hindrance to the Execution and Performance of the Machine. Fill such a Tube with pure Mercury, which may be best done by Help of a small Funnel that will suffer it to pass only in very small Drops; by the successive falling whereof into the Tube, the Air will be extricated from the Mercury pretty well; and the Column of Mercury viewed thro' the Glass, will then resemble a Rod of Steel finely polished. Stop the End with your Finger, invert it, and slip it suddenly off into an open Vessel, having other Quicksilver in it. Part of the Mercury will thereupon descend, and fall

into the Cistern, and the rest will be sustained in the Tube to the Height of twenty-nine Inches and a half above the Surface of the Quicksilver, in the Cistern, if the Air happens to be of a middle Weight, and the Weather *changeable*. If it be inclined to *fair*, the Mercury will stand somewhat higher ; if *foul*, it will settle something lower.

To prove that it is the Atmosphere's Pressure on the Surface of the Quicksilver below, which supports the Mercury in the Tube ; put the Barometer, thus made, under an Apparatus that may be exhausted of Air ; and as this by the Pump is gradually done, the Mercury in the Tube will be seen to fall proportionably. When the Air is wholly drawn off, the Mercury will lie quite level at Bottom of the Cistern ; and when the Air is let again into the Receiver, the Mercury will be pressed up again thereby, and rise to the Height it stood at before. This Experiment is represented *Fig. 5. Plate 7.*

THE immediate Cause of this Appearance, is doubtless from the Inequality of the Air's Pressure on the Surface of the Fluid. Before exhausting, the Air pressed every Part of the Cistern of Mercury, except the Spot just beneath the upright Tube ; the Top whereof was however then equally pressed by a Column of Air of like Base and Weight with itself, which, had the Tube not displaced and transferred its Pressure elsewhere, would have been incumbent also on that very Spot. During the Exhaustion, the Air's Pressure is gradually removed from off both the

Mer-

Mercury and the Tube. When the Exhausting is finished, these being encompassed with Space void of Matter, and therefore without sensible Weight, the Mercury remains on a Level, merely from the simply Direction of Gravity; but when, upon Admission of the Air, a casual Pressure is again laid both on the Mercury in the Cistern, and the external Part of the Tube there-to exposed, (Vacuity from its Situation and Circumstance being still preserved within it) the Rise of the Mercury into the Void shews the Degree of the prevailing Pressure of the Air and its Limits.

To make this Matter plainer if possible, let us attend to the following Experiment, made on a Fluid less dense than Mercury. In order to which, exhaust a Receiver, set on a separate Plate, of its Air, as represented in *Fig. 6. Plate 7.* and you will have a portable Vacuum. Screw in a Pipe below; immerse the End in Water, and on opening a Cock, the Fluid will rise into the Receiver in a very smart Jet, which if required would mount perhaps thirty Feet high merely from the Pressure of the external Air. And was the same Experiment to be made on Mercury, the Jet would be found to play just as high as the Mercury in the Barometer would stand: Nor indeed is this any other than a Barometer in another Form.

INEQUALITY of Pressure, is in general, we are sensible, the Cause of all Motion; and fluid Bodies very readily shew where and how they are

are press'd, by yielding the contrary Way: If the Pressure comes from the Right, for Instance, they give way to the Left; if from above, they always subside; if from below, they constantly rise, that the Equilibrium established in Nature may be uniformly preserved.

BEFORE we proceed farther on this Head, it may not be improper, for the sake of Perspicuity, here to introduce a short Description of the modern *Air-Pump*.

On the AIR-PUMP.

THE Air-Pump was first invented by OTTO GERICK, of *Magdeburg*; but was rendered more practicable by Mr. BOYLE; and it hath since his Time been greatly improved. *Fig. 7. Plate 7.* is the Representation of the Pneumatick Machine now in Use; wherein *A* is a Receiver, ground level at Bottom, set on a wet Leather, covering a flat Plate *B*, to be exhausted of its Air occasionally; which being a Body dilating by its natural Spring, and therein confined, pushes gradually from the Receiver, thro' the crane-necked Pipe *C*, as far as the Cistern *D*, wherewith the two Barrels *EE* communicate; and into which it gets from beneath the Bladder-Valves tied over the Holes made for that Purpose, under either Barrel one.

IN each Barrel is a moving Piston, leathered upward, that it may shut off the Atmosphere above, as *FF*. These are drawn up and thrust down

down alternately therein, by Means of a circular Wheel full of Teeth, *G*, and a pair of Racks, marked *R*, to fit those Teeth, thereby constantly moved, the one up, the other down, when the Pump is in Use, by means of a Crank of very curious Contrivance, *P*, at every regular Revolution of the Winch or Handle *H*. The Racks are kept from flying off from their Work by Rollers behind, which also ease the Friction.

In each of these Pistons is such another yielding Valve placed, opening also upwards into a perforated Duct, by which the Air extruded from the Barrel at every Stroke of the Pump, when the Pistons descend, may get away. The Action of the two Valves, belonging to each Barrel, is as in the common Pumps, also alternate.

THE upper Air being closely shut from off the Barrel by the Pistons and Piston-valves, whenever those rise, Room is given for the internal Air of the Receiver to dilate, which by its elastick Quality it always endeavours to do, and a Part of it thereupon pushes out of the Receiver, thro' the nether Valve, into the Chamber of the Barrel, where a Vacuum was left on the Rise of the Piston. This, whenever the Pistons descend, they would again condense, did not the upper Valve, on the shutting of the other, give Way, and thereby suffer it to escape.

By this Means do we gradually get rid of most of the Air included in a Receiver; and
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so long as the Air is dense or gross, we part with it apace: But when it is much attenuated, it lifts the Bladder-valves of the Pump but weakly; the Operation then becomes more slow; and when it is very much thinned, it will want Spring and Power to lift them at all. For which Reason, by the common Air-pump, the Air cannot be perfectly exhausted from our Receivers, though as near as is 59 to 60 it demonstrably may, if the Machine be good.

THE Racks and circular Wheel before mentioned, in the ordinary Air-pump, are used sometimes to be turned by the Handle, first this way, then that, stopping every Time the Rack comes to the Bottom of the Barrel, by which Time in making Experiments is lost: But the late Mr. VREAM found out a Method of sinking and raising the Pistons, with a regular uniform going round of the Winch, whereby a Crank was always seemingly turned directly forward. Now this Crank being communicated by Straps to the circular Wheel moving the Pistons up and down, into which they were also fixed in a moving Centre, pitched at some Distance from the true Centre of the Wheel, in such manner that the Straps never passed the said Centre; but when by half a Turn of the Winch and Crank, the Rack of one Piston had been depressed, by the other half Turn it was brought up again, and the other Piston thrust down: And this was alternately done by the Rolling of the circular Wheel backwards and forwards, moved, as was said before, at every Revolution of the Winch and Crank,

Crank, always kept in Motion directly forwards. In the Draught this Contrivance is pretty well represented; and it might be applied to the raising of Water with two Pumps, worked by a Water-wheel in the same manner, were there not in Use other Methods for that End less liable to Friction.

To prove that the Air is really exhausted, or at least very greatly attenuated, in the manner before spoken of, by the Air-pump, take a Receiver open at both Ends; the taller the better. Cover it with a Plate, having a wet Leather between it and the Glass; to which let there be an Apparatus with a Hinge fixed, with a Contrivance coming thro' a Collar of Leathers, that it may discharge or let a Guinea and a Feather, put Side by Side thereon, go at the same Instant. Exhaust the Receiver, and let them drop together. Tho' one of these be the densest and most ponderous of all the material Substances we know, and the other one of the laxest and most light, yet shall they in this Case fall equally fast, and visibly come down on the Leather exactly together. Which will demonstrate, that the gross Air, always resisting; and considerably retarding the Fall of light Bodies, is by the Pump really removed; and at the same time shew, that *in Vacuo*, Gravity affects all Bodies equally. This Experiment is represented Plate 7. Fig. 8.

MOREOVER, by Means of a Barometer communicating with the Receiver, fixed beneath the

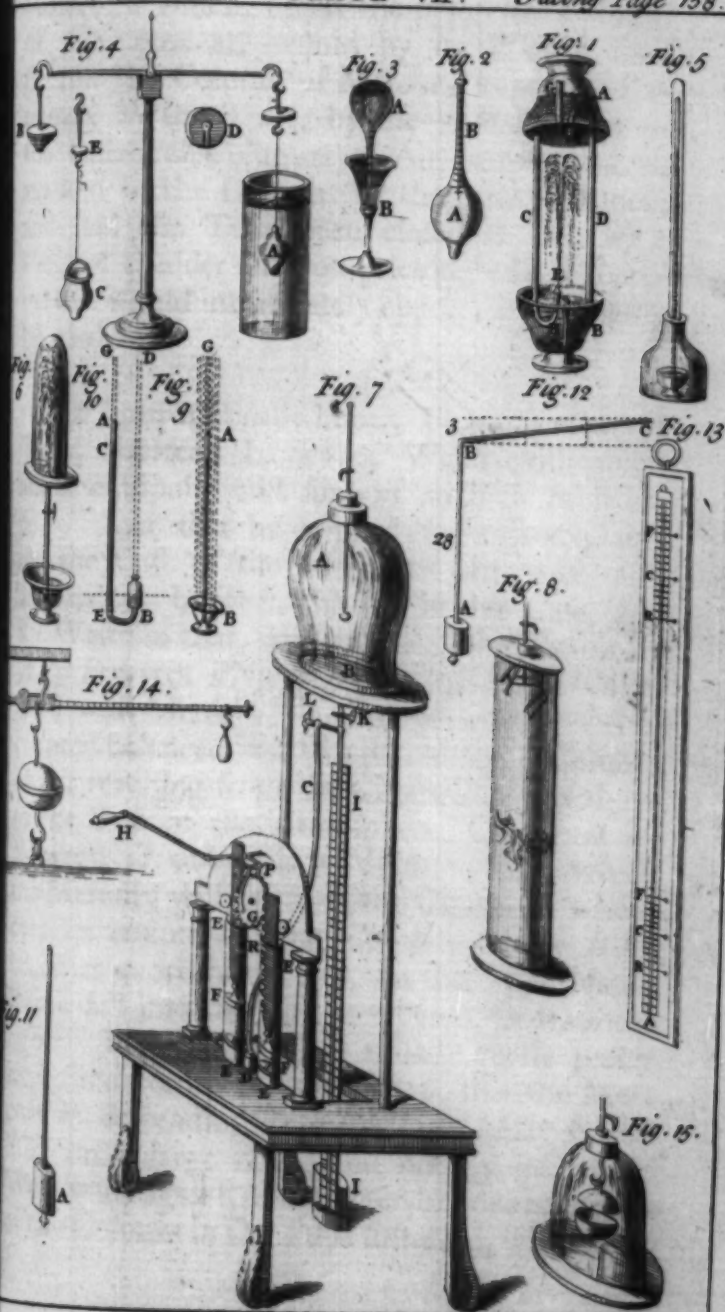
the Frame, otherwise called the Gage-tube, marked *I*, we are able to discover the gradual Approaches made towards a Vacuum, by the Rise of the Mercury therein, from the Cistern at Bottom by the Air's external Pressure, always visibly increasing in a regular and just Proportion to the Abatement and Removal of the Air within; as may be observed in the Experiment of exhausting the Air, in order to bring down the Mercury mentioned *Page 152*, to very good Advantage.

THE Gage-tube may, on Occasion, be shut off from the Receiver by the Cock *K*; and *L* is another Cock, whereby the external Air may easily either be shut off during the Time of exhausting, or admitted again into the Receiver after 'tis over.

The CASE of the BAROMETER resum'd.

IT has been already hinted, that the Column of Mercury *AB*, in the Barometer, *Fig. 9. Plate 7.* was of a just Weight with a Column of Air of like Diameter with the Orifice of the Tube, reaching from the Cistern *B*, to the Top of the Atmosphere; which Column *GA*, now pressing the Top of our Tube at *A*, was the Barometer removed, would necessarily press the very Point on which it now stands: But in the present Circumstance, a Quantity of Mercury adequate thereto in Weight, is substituted within the Tube, in the Room thereof; the

Surface



NATURAL *and* ARTIFICIAL

surface of which, could the beforefaid Air come at, would by its Weight depress the Column of Mercury kept stationary in the Tube, by the joint Pressure of the collateral Columns of Air surrounding it. Marked in the Draught by the prickethole, and had the Tube been closed at the top with a piece of Bladder only, on pricking a Hole in it, this would immediately appear, as may be tried.

WE hystrostatically know, That in a Tube, fourteen Inches of Water will about equipoise and support an Inch of Mercury. Let this be applied towards understanding the Case of the Barometer before us. An Analogy between the Air in this Case and the Water in that, will appear. For in *Fig. 10. Plate 7.* is a barometrical Tube filled with Mercury, standing between two Cisterns, counter-balanced and supported by a Column of Air reaching from the Cistern *B*, open to the Top of the Atmosphere, supported by the Air Between *A* and *C* is a Vacuum, in which the Mercury will rise from the Cistern *B* till its counter-poising Column of Air becomes more heavy; as, on the other side, it will fall into the Cistern when it grows lighter. The Cistern *B* is usually made large, and commonly cylindrical, that the Weight in descending from the Tube, may rest on a large Area, and not by its Weight act against and counter-balance the Column in the Tube sustained, which

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it small or narrow, it necessarily must do. For the stationary Height of the Mercury is always to be reckoned from *E*, lying in the same Plane with *B*; whither it will, when at Liberty, rise from the Cistern, as to its own Level.

WAS the Atmosphere of the same Density from the Bottom to the Top, it would be no great Difficulty, by the help of the Barometer, to determine its Extent; it could not exceed five Miles and a half at most: But as the Air is a dilatable Fluid, expanding itself in proportion to the Abatement of Pressure above, as also by the Increase of its Spring from Heat and other accidental Causes, we are not able to speak of its Height with any great Certainty. Most of the Learned however judge it to be sensible to the Height of sixty Miles; others to forty-five, still growing thinner and thinner as it leaves the Earth, where the Air is densest, the most compress'd, and therefore the most fit for animal and vegetable Use.

AND that the Air is really thus compressed near the Earth, will appear on tying up a small Quantity of it in a pliant Bladder very close, putting it under a Receiver, and exhausting the Air from about it. For when the Pressure of the outward Air is remov'd, the inclosed Air will dilate itself every way, and swell the Bladder greatly; so much that if it had happened to be well blown up before, and well tied, it wou'd very probably have been burst by the Experiment. The like would also happen

happen; at least in some Degree, was a Man to carry a flaccid Bladder from the Foot of a Mountain to the Top; it would be sensibly found to grow more and more turgid, and that in Proportion to his Ascent; and the Abatement of the Air's Pressure from without.

LET the Air then be consider'd as a spongy compressible Body, something like Wool: If a Handful of which be pressed close together, it will, we know, be reduced into a very narrow Compass; but when left at Liberty, it will recover its former Bulk, by Virtue of the natural Spring of its Fibres. And accordingly, were Fleeces of Wool laid on the Floor, suppose ten Feet deep, the nether Parts must be more compressed than the upper, and that in Proportion to the incumbent Weight: And again, if these Fleeces be gradually removed, the Fibres of the Wool being elastick, will stretch forth, unbend themselves, and occupy more Space than in a State of Compression they could do.

THUS is it with the Air: If we abate the Pressure by ascending an Eminence, Doctor SCHEUCHZER's accurate Experiments made on the Mountains of *Switzerland*, inform us, That by the Time a Man is seven hundred and ninety Foot above his first Level, the Mercury in the Barometer, in settled Weather, will have subsided an Inch; at the Height of sixteen hundred and ten Foot and a half perpendicular, it will have sunk two Inches; at

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two thousand four hundred sixty-five Feet and a quarter, the Difference will be three Inches; at three thousand three hundred and fifty-six Feet, four Inches; at four thousand two hundred and eighty-six Feet, five Inches; and at five thousand two hundred fifty-five Feet and a half high, the Mercury will stand six Inches below what it would have done at the Level of the Sea: Whence it appears, that the Stages determining the Descent of the Mercury (an Inch for the first six) are severally very different, being denoted nearly by the Numbers 790, 820, 855, 891, 930, 969; which Spaces therefore would continue increasing till the Atmosphere above should be of no Weight; by which Time the barometrical Mercury would be of no Height.

ON the contrary, should the Air's Pressure on the Surface of the Earth be any way augmented, as by descending into a deep Mine, by the Time a Man should be seven hundred and sixty Feet under Ground, perhaps, the Mercury will stand in the Barometer an Inch higher than it did at the Surface. But such a Descent being neither practicable or over-safe, and as we have found that Water is about eight hundred and fifty times heavier than common Air, 'twill do as well to immerse the Barometer, standing according to the Pressure of the Air on the Earth's Surface at a certain Height, into ten or eleven Inches of Water; and if the Mercury thereupon rises about an Inch, we may thence conclude, that if the Barometer had been let

down

down seven hundred and sixty Feet below the Surface of the Earth, the Effect had been the same.

THE portable Barometer is the properest Instrument for this kind of Experiments, which differs from the Toricellian only, in its having the superfluous Mercury, or what is more than necessary to form the stationary Column of the Fluid, instead of being in an open Cistern, as *B*, *Fig. 9. Plate 7.* inclosed in a Box, as *A*, *Fig. 11. Plate 7.* in the Bottom whereof is a loose pliant Leather, having so much Play left, that it will easily become either concave, and so let down the Mercury from the Tube when the Air grows light; or convex, and so thrust up Part of the contained Mercury into the Tube when it becomes more buoyant, and presses harder against it. Underneath the Box is a Screw fixed, and a false Bottom fitting the Leather, whereby the Mercury may, for the Convenience of Carriage, be raised to the very Top of the Tube, and kept from jogging to and fro to endanger its breaking.

As Fluids at Liberty and unconfined always endeavour to maintain the same perpendicular Height, the barometric Mercury, whatever Inclination be given the Tube, being still under the same Degree of Pressure, will do the like. In which Case there will indeed be more Mercury thrust into the Tube, which being slanted, becomes an inclin'd Plane, and which therefore on its Sides is expected to support the Difference

of the Weight of Mercury contained between the perpendicular and slope Heights.

ON this Account, some have endeavoured to augment, or at least to magnify, the Divisions on the Scale of the Barometer, that the Alterations happening in the Weight of the Air might be the easier perceived; and accordingly have contrived a Tube, running straight to twenty-eight Inches, as *AB*, *Fig. 12. Plate 7.* and then bent by such an Angle as will bring the upper Part to be about thirty-one Inches above the Cistern. If the Diagonal *BC* be thirty Inches long, the Rise of the Mercury one Inch perpendicular, will cause it of course to traverse ten Inches of the Tube diagonally. But as there must consequently be, in this Case, ten times more Friction between the Mercury and the Machine, as well as ten times the Attraction, this Instrument is in Practice found seemingly less exact than the other.

SHOULD the barometrical Tube be taken suddenly out of the Cistern at any Time, it may be observed, that the Column of Mercury, ordinarily standing some Inches below the Top of the Tube, will thereupon rise, and strike against it with a kind of Shock. The Reason of which is, that by the Suddenness of the Motion, Part of the Mercury will be made to quit the Tube, from the *Vis Inertiae* of Matter; and the Remainder of the Column not being a full Counterpoise to the Atmosphere pressing against it below, 'twill therefore

therefore be pushed against the Head of the Tube with a Force equal to the Difference of the two Weights; just as one Arm of a Balance rises with Force, or kicks up, when its Antagonist is over-charged with Weight.

It might therefore be expected, that the whole Column of Mercury, in this Circumstance, would be buoy'd up, or kept suspended by the Push of the Air; and thus it would really happen, as in the pendent Barometer it does, was the Tube small, and held exactly upright; or otherwise, one Part of the lower Surface of the Mercury becoming something longer than the rest, by over-weighing and falling out of the Tube, would disturb the rest, and incline them also to follow: For the Demonstration whereof, see Page 76. before-going. If some Water be purposely put on the Mercury in making this Experiment, as the Mercury gradually descends from the Tube, the Water, by the Weight of the Atmosphere, will be forced up into the Vacuity, and fill the Pipe; which will give us another evident Instance of the Air's Pressure, and intimate the Manner in which it acts in *Hydraulicks*, or the Practice of raising Water for Use by the various kinds of Pumps.

HAVING mentioned the Pendent Barometer, the Description of this Machine, as made by the late Mr. PATRICK, will not be disagreeable to the Curious. The Tube *A*, Fig. 13. Plate 7. is straight and slender, somewhat conical, hermetically seal'd at Top, and is commonly

monly five Feet or better in Length. The nether End is open, and always freely exposed to the Air. The Tube is to be filled with Mercury purged of its Air, and turn'd gently down. What Mercury the Air shall not be able to support, will thereupon fall away; the rest will return, vibrate, and hang ready, either to rise in the Tube on any accidental Increase of Weight in the Air, or to sink in it, in Case of any Abatement therein; and by due Observation, on a regulating Barometer the Marks may be afterwards added, and the Scales graduated as Opportunity offers.

THIS Instrument has usually two Scales to observe by; at either End of the Column of suspended Mercury one. These are commonly somewhat different in Length, and the Divisions not equal: For as the Tube is a little conical, the Column of Mercury will necessarily be shorter in one Part of it than in the other. The Scales therefore of this Barometer are always to be adapted severally to each Tube.

THE Mercury in this Machine, instead of rising and falling three Inches, as in the common one, will move in some ten, in others twenty or thirty Inches perpendicular (according as the Tube happens to be more or less taper) which makes the Alterations in the Air's Weight very perceptible thereby: It is therefore a very good but not a cheap Barometer; not one Tube in a hundred being fit for the Purpose. If they be nearly cylindrical, or over large, they will not do at all.

*Directions for observing the WEATHER
by the BAROMETER.*

BEFORE we have done with this Subject, it may not be amiss to subjoin the Directions which the said Mr. PATRICK, after long Experience, has given as the standing Rules whereby the Alterations of the Weather might be generally prognosticated by Help of the Barometer, and which are to be rationally accounted for on the Principles herein laid down.

1. THE rising of the Mercury presages in general, fair Weather; and its falling, foul Weather, such as Rain, Snow, high Winds and Storms.

2. IN very hot Weather, the falling of the Mercury indicates Thunder.

3. IN Winter, the Rise of it prognosticates Frost; and if, in frosty Weather, the Mercury falls three or four Divisions, there will certainly follow a Thaw: But in a continual Frost, if the Mercury should rise, it will certainly snow.

4. WHEN foul Weather happens soon after the falling of the Mercury, expect not much of it. And on the contrary, expect but little fair Weather when it follows soon after the Mercury has risen.

5. IN foul Weather, when the Mercury rises much and high, and continues so for two or three Day before the foul Weather seems quite over, you may expect a Continuance of fair Weather to follow.

6. ON the contrary ; if in fair Weather the Mercury falls much and low, and so continues for two or three Days before Rain comes, you may then expect a great deal of Wet, and probably high Winds.

7. THE unsettled Motion of the Mercury denotes uncertain and changeable Weather.

8. THE Words graved on the Plates are not strictly to be minded, tho' for the most part the Weather will also agree with them, as to the Rising and Fall of the Mercury : For if it stands at *Much Rain*, and then rises to *Changeable*, it presages fair Weather, tho' it will be of a shorter Duration than had the Mercury been higher. And on the contrary ; if the Mercury being at *Fair*, should fall to *Changeable*, it indicates foul Weather ; but not so much of it as if it had sunk lower.

IN order therefore to pass a right Judgment of what Weather is to be expected, we ought to know whether the Mercury be inclined to rise or fall ; in determining of which, the following Rules will be of Use.

1. IF the Surface of the Mercury in the Tube lies convex, that is, higher in the Middle of the Tube than at the Sides, it is generally a Sign that the Mercury is rising.

2. IF on the contrary, the Surface of it appears concave, or hollow in the Middle, it is certainly sinking.

3. IF its Surface seems to be plain, the Mercury is stationary; or rather if it be a little convex: Since Mercury, being put into a glass Tube, especially if it be small, will naturally have its Surface a little convex; because the Particles of Mercury attract each other more forcibly than they are attracted by Glass.

4. IF the Orifice of the Tube be small, always shake the Barometer when you wou'd observe; and if the Air is growing heavier, the Mercury will ordinarily rise about half a Tenth of an Inch, perhaps higher than it stood before; if 'tis growing lighter, it will sink as much. This proceeds from the Adhesion of the Mercury to the Sides of the Tube, which prevents the Freedom of its Motion, till the Parts are disengaged by the Shock; otherwise the Mercury may not move of its own Accord, perhaps, till after the Weather it ought to have indicated is past. But if the Orifice of the Tube be a Quarter of an Inch or more in Diameter, no such Precaution is necessary.

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Some EFFECTS of the AIR'S PRESSURE described.

WHEN the Pressure of the Air was first discovered, according to the Fate of all considerable Inventions, it met with Opposers, who objected, That if the barometrical Column of Mercury was really supported by the Air, it ought to have no Weight when proved by a Balance; which on the Trial will not appear.

THE Air's Pressure, by the fore-mentioned Experiments being undeniably proved, makes this Objection scarce worth a Reply. However, to prevent the Triumph of such as had rather contend for Victory, than ingenuously submit to Conviction, and own the Truth, we answer: That the Materials of which the Barometer is made, are all equally press'd, and equally buoyed up by the ambient Air, as well separate, as when put together; they are therefore, in either Circumstance, of the same absolute Weight. And tho' the Column of Air, *Fig. 10. Plate 7. B D*, or one in all Respects equal thereto, does certainly sustain the Column of Mercury *EC*, in the Tube, which has a Vacuum of no Weight above it; yet as there is a Column of Air *AG*, very nearly of equal Weight with *B D*, pressing on the Head of the Tube, and not to be removed thence; therefore it is that on the Experiment, no Difference in Point of Weight appears. Whereas, was the

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Experiment to be made on a Tube that would reach beyond the Limits of the Atmosphere's Pressure, or could the Pressure of the comparative Column of Air *AG* by any Means be removed from off the Head of the Tube, no doubt a considerable Difference, equal to the Weight of the Column of Mercury supported, would then be found.

In like manner, the Pillar of Mercury in the Pendent Barometer, which is evidently supported by the Pressure of the Air beneath, is no manner of Weight on the Hand; but yet, as a counterpoising Pillar of Air must be allowed to depress the upper Part of the Tube without, just as much as the Mercury therein supported may be allowed to weigh, no Difference in point of Weight can appear; and our Senses may be admitted easily to deceive us in this Case, as to the Thing we do certainly lift.

It also may be considered, that in working the Sucking-pump, it is not the Weight of the Water drawn, that lies a sensible Burthen on the Hand; for that is evidently weigh'd, or push'd up the Pipe, by the Incumbency of the Atmosphere on the Water in the Well: But then in order to make the *Vacuum*, that it may rise, we lift a Weight justly counterpoizing the same, *viz.* that of the Column of Air, unavoidably resting on the Bucket above.

THE determinate Quantity of the Air's Pressure depends on the State thereof at the Time

of Trial. When 'tis heaviest, fourteen Pounds eleven Ounces Avoirdupoise is found to press on every superficial Square Inch contained in all Bodies exposed thereto; and fourteen Pounds one Ounce when it is lightest. At a Medium, a circular Inch is subject to the Weight of about twelve Pounds, so much being required to raise the Piston of an exhausting Syringe, well clos'd at Bottom; which therefore we may take as the general Standard for finding the Quantity of the Air's Pressure on any circular Plane whatever (since the Areas of Circles are proportionate to the Squares of their Diameters) by this Analogy:

*As 1, the Square of the Diameter of one Inch,
Is to 12 Pounds, the general Pressure thereon:
So is the Square of any Diameter proposed,
To the Air's Pressure on the Area of the Circle
correspondent thereto.*

To prove this Fact; take a Pair of brass Hemispheres, suppose three Inches and a half over. Put a Ring of wet Leather between their Edges, which ought to fit each other very well. Exhaust the Air from between them, and they will require a Pull, as by the Steel-yard may be tried, of near an hundred and fifty Pounds to part them; and yet they will fall asunder by their own Weight in *Vacuo*. The first of these Experiments is representd Fig. 14. the other Fig. 15. Plate 7.

THE Weight of the Air will be always sensibly felt, on drawing up the Piston of an exhausting

hausting Syringe, as above: Since it will be forced down by the Pressure of a Column of Air correspondent thereto in Diameter, of the Height of the whole Atmosphere; and if its Bore be three quarters of an Inch in Diameter, the Hand that makes the Experiment will find very near the Resistance of seven Pounds, if the Weather be inclined to Fair and the Instrument free and perfect. But yet, whenever this Machine also is put under a Receiver, and the Air exhausted from about it, the before said Weight thereto annexed will evidently sink: But when the Air is readmitted, and comes again to press on the Piston on one hand, and against the Weight on the other, it will rise and return to its former State.

AND since so great a Force as twelve hundred Pounds is required to separate two circular Planes of but ten Inches over, kept together merely by the Force of the Air, it is thence easy to judge of the very great Pressure lying constantly on the Body of a middle-sized Man, the Surface whereof will be found ordinarily to measure to about twenty square Feet. This, from the evident Experiment beforementioned, can never be less than forty thousand five hundred Pounds; but on occasions may amount to the Weight of forty-two thousand three hundred Pounds, or one and twenty Tons and one seventh.

THE general Pressure of this Fluid may be aptly compared to a strait and general Bandage,

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made equally on every Part of the Body, the Sum total whereof would amount to the Pressure just named ; which if laid on any particular Part of the Body, would no doubt inevitably crush it : But as the Body is in every Part loaded alike, 'tis embraced, and as it were bolster'd up by it on every Side.

THIS external mighty Force would be insufferable, and even fatal to us, was not the Air we breathe taken into our Lungs, mixed in plenty with the Blood, and after that circulating with the Mass of Fluids throughout the Body, of equal Force with the external, and therefore able to repress and counterbalance the enormous Pressure from without : Just as the Air on the Right Side of us, bears against and resists the Pressure it makes on the Left, whereby we are freed from the great Suffering and Violence which otherwise we should soon be sensible of to our Cost.

To evidence the Truth of this : Take only an open circular Glass four or five Inches over, covered with a stout Bladder, like the Head of a Drum. So long as the Air presses this Membrane on both Sides equally, it is observed to lie streight, at rest, and truly level ; but it can no sooner be set on the Pump, and Part of the Air exhausted, but the outward Air will visibly depress the upper Surface of the Bladder into a concave Form. On letting the exhausted Air in again, it will immediately return to its former Situation ; but should it be continued, by the
Time

Time the under Air is greatly attenuated beneath, and the Resistance of it by consequence nearly removed, the yielding Substance will probably give way to the upper Force, in a very audible Manner. For as there is a Vacuum made within the Glass, the whole Body of the adjacent Air, on the Bursting of the Bladder, will by its natural Spring immediately move, to make good the Deficiency : And so far as the Air shall be sensibly shaken by the Suddenness of the Shock, so far the Sound of the Bursting will be heard, like the Noise of Fire-arms, and for somewhat a like Reason.

On the Art of DIVING.

ANOTHER Way of considering the Pressure of the Air is, by comparing it with its adequate Weight of Water. It is known to counterpoise at a Medium, about thirty-three Feet of Sea-water, a cubic Foot whereof weighs experimentally sixty-four Pounds; of consequence therefore, the Body of this Fluid must press at least with the Force of two thousand one hundred and twelve Pounds on every superficial Foot near the Surface of the Earth, where, as has been said, the Atmosphere is generally the most compressed. Should however, any Quantity of this Fluid be by any Means conveyed to the Depth of thirty-three Feet of Salt-water, it would, lying under the Weight of a double Atmosphere, be there doubly compressed, and forced into near half the Space it took up on the surface. Should it be farther immersed to the Depth

Depth of sixty-six Feet, its Dimensions would be still much more contracted, as being under the incumbent Weight of a treble Atmosphere; it will then be found to take up but one third of the Space it held at first: And at ninety-nine Feet below the Surface, it will be crouded into one fourth of the Room it at first took up.

For this Reason, the Divers, who are obliged to go down to great Depths in Water, if they have only Air of common Density, in their Bodies, which has been commonly conveyed to them in Pipes from the Surface, always find themselves greatly oppressed by the Weight of the Water above them. A Person, who from the surface of the Earth having only common Air in the Vessels of his Body, is but ill provided to sustain a double or a treble Weight from without; and the additional Pressure will doubtless be a great Incumbrance to him, how equally soever the Weight may be distributed and laid on every Part.

'Tis a common Experiment with the Sailors to sink a Bottle well cork'd, with only common Air in it, to a good Depth in the Sea, that on pulling it up they may find, as they generally do, the Cork forced into the Bottle by the external Pressure of the Water.

A noted Diver, not long since, in thirteen Fathom Water, having the Trunk of his Body cas'd in Armour, had his Arms, which

were only covered with Leather, so squeezed, that the Circulation was almost stopped, and the Blood was forced out of his Eyes, Nose and Ears, by the very great incumbent Pressure, which had nearly closed his Blood-vessels. He lay six Weeks by the Hurt he received in this Experiment. And tho' he saw a Cask of Dollars but at a small Distance from him, it was not in his Power to get at it; and his Companion, venturing a little further, was near expiring when he came up, and actually died in three Days time.

IN order therefore to remedy this great Difficulty, and to render Pearl and Coral-fishing, and the Recovery of Things lost by Shipwreck, more practicable, the Diving-bell was invented; which is a stout Machine, made of Wood or Copper, Bell-fashion, about eight Feet high, and as much in Diameter, at Bottom; this Form being the most advantageous of any for the Purpose, because of its great Capacity downwards, whence it may happen, that when the Bell is really half full of Water, it may not exceed perhaps two Feet deep in the Machine. It has Seats within, for the Divers to rest themselves upon. It is hung round on the Out-side with Weights, so disposed as to make it sink with the Mouth downwards, in a perpendicular Position. The Model of the Bell *A*, and the Utensils, you have represented *Fig. 1. Plate 8.* which being put into a large Jar of Water, answers all the Experiments perfectly well.

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THE real Machine, having three or four Men in it, with proper Instruments for the Business proposed, may be let down by the Yard-arm of a Ship, upon the Wreck or Vessel lost, to the Intent that the People within may break up the Hulk, and fasten Ropes to Cannon, Casks, or any other Thing worth bringing up; and then the Sailors above, on a proper Signal given, stand ready to weigh them up with Tackles, by Force of Hands.

As the Machine is lower'd in the Sea, the Air within will of course be gradually compressed by the Weight of Water above, constantly endeavouring to push into the Bell, and will consequently rise therein by Degrees; so that at thirty-three Feet deep, it will be one half, at sixty-six Feet, two thirds, and at an hundred Feet deep, it will be about three quarters full of Water, agreeable to what was offer'd of this kind, *Page 64.* This Condensation of Air will not however by its increasing Pressure greatly affect the Persons in the Bell, tho' it really be of equal Force and Resistance to the whole Weight of Water whereby it is compressed: Because as it is always to be let down slowly, the People have Liberty to respire the Air condensed during the whole Time of its Descent.

FROM the Capacity of the left Ventricle of the Heart, whereby the Blood is thrown out into all Parts of the animal System between every Pulse, seventy-five of which are generally made

in a Minute when the Body is in Health; and as the Quantity of Blood requisite to fill all the great Vessels in a human Subject, is usually estimated at about twenty Pounds, Anatomists thence judge, that the Circulation of the greatest Part of the Mass of Blood, thro' the Lungs, must be performed in about five or six Minutes. The Divers, in their Descent, are from hence internally provided by Degrees, to sustain the great and prevailing Pressure from without, to which the internal Air of the Body must be necessarily a proper Antagonist at all times, and in *Equilibrio* with it, or else most fatal Effects would immediately follow.

AND as this Machine is to be deliberately lower'd, so is it to be rais'd, lest the Air taken into the Mens Bodies, at the Bottom of the Sea, in an extraordinary Degree of Compression, should by its natural Spring evolve itself too suddenly, in case that Pressure is precipitately withdrawn; by which Accident, rending the Coats of the Vessels might bring on immediate Death.

THE Diving-bell thus answer'd the Intention of the Contrivers pretty well; but some Inconveniencies still attending it, Dr. HALLEY undertook to improve it. As it contained but four or five Hogsheads of Air perhaps at first, when it came to the Bottom of the Sea these were reduced into the Bulk perchance of one. Now by Experience it is found, that a Man requires about a Gallon of fresh Air to subsist

on a Minute, and less than a Hoghead will scarce serve him an Hour: Because the sulphurous Effluvia from the Blood either absorb or vitiate the wholesome Quality of the Air, or, by blunting its Particles, render it in Time effoete, unfit for Respiration, and even poisonous.

A second Objection to the original Diving-bell was, the Want of Light. This obliged them to take down Candles. And a lighted Candle spoils as much Air as a Man may use: Which is proved, by setting one under a Glass Receiver, represented *Plate 8. Fig. 2.* full of common Air, on a wet Leather, to prevent a Supply; which, when either consumed or corrupted, the Candle soon of itself goes out. And no doubt but an Animal in like Circumstances, would sicken and faint in a very short Time; whence Mr. PAT. GORDON, in the fifteenth Paradox of his *Geographical Grammar*, asserts, *That there is a remarkable Place in the Globe of the Earth, of a very pure and wholesome Air to breathe in, yet of so strange and detestable a Quality, that it is absolutely impossible for two of the entirest Friends that ever breathed, to continue in the same in mutual Love and Friendship, for the Space of two Minutes of Time.* This must be where they had scarce four Gallons of Air or that Quantity of Space more than their Persons would possess.

A third Objection to the original Diving-bell was, That when the Air made use of be-
came

came hurtful to Life, there was no way of getting rid, or of shifting it; and the former Quantity of Air, being thus reduced by Compression to the Compass of one Hoghead, four Men and a couple of Candles could scarce subsist therein ten Minutes: Which being too short a Time to pass up and down, and do much Business in the Diving-way, the Invention in this Particular fell also very short of Perfection.

THE Doctor removed the first of these Objections, by fixing a Cock in the Head of the Machine, to let out the vitiated or corrupt Air, when necessary, as at *B*. This succeeded very well. The warm Air being lighter than the cold, always rose above, and was therefore first pushed forth. Nor was the Pressure of the Water on the Hole of the Cock above, able to confine it in the Bell; because the Column of Water condensing the Air, and endeavouring to push in at Bottom, was about eight Feet longer, and consequently much heavier than the Column pressing on the Cock at the Head of the Machine.

WHENEVER the corrupt Air was let loose, the Surface of the Sea was put all in a Foam: For as the Air, in its natural Degree of Compression, on the Surface of the Earth, unwinds or expands itself to very large Dimensions; when rid of that Pressure, it will doubtless expand in the same Manner, to a still greater Degree, when contracted into one fourth of the space: And a Portion of Air, at the Depth of a hundred Feet, about the Bigness of a Hazel-

Nut, might become perhaps as large as an Orange at the Surface; whence the Appearance just mentioned may very reasonably be supposed to proceed.

To supply the Bell with fresh Air, the Doctor contrived to have a Vessel somewhat like a Barrel, with one Head only, or in Fact a smaller Bell, as *C*, *Fig. 1. Plate 8.* kept going continually between the Surface of the Water, where it still took in fresh Air, and the principal Machine. This Vessel being sunk a little lower, had the Air therein more compressed than that in the larger. Into the Head of the smaller was fixed a strong leather Pipe, with a Cock at the End, which one of the Divers took and turned whenever they wanted a Supply of fresh Air, which was easily received into the larger Machine. This Contrivance not only afforded them a continual Supply of wholesome Air; but by its elastick Power emptied the Bell of Part of its Water, and consequently gave them more Room to move and act in.

A strong Lens, eight Inches over, was fixed at the Head of the Machine, as *D*, to give them Light, with the convex Side downward, in order to spread the Light as much as possible within the Bell: Which so well succeeded, that the Doctor says he has read a *Gazette* at the Bottom of the Sea in calm Weather; but in a Gale of Wind, the Rays of Light being frequently broken by the Motion of the Water, this Cabbin was somewhat darkened.

THIS ingenious Gentleman at length brought Matters to so great a Degree of Perfection, that he could detach one of his People from the principal Machine, to any proper Distance, with something like an inverted Hand-basket of Lead on his Head, as *E*, so shaped that he might see his Way, and what lay before him. In the Top of which was fixed a flexible Pipe, like that belonging to the Vessel, for transmitting fresh Air when wanted. The Person, by turning a Cock, could supply himself from the Bell, if he mounted a little higher than the Place of Communication, whence the Air would then naturally rise into this his Helmet; and being denser than the Air us'd and spoil'd in his own Machine, would therefore extrude it. And this was so contrived, that had any Accident happened to the Person sent out, or if he neglected to turn his Cock, and so to endanger the Bell by the Loss of the Air, the People within had another Cock at command, by shutting whereof the ill Consequence of such an Accident might have been avoided. And as such a Person came gradually into Air of a fit Density to repel the very great Pressure of the Water in so considerable a Depth, he had of course respir'd it sufficiently to fortify his Body against the external Pressure at that particular Depth of Water, and therefore could not be oppressed by its Weight on his quitting the Bell.

THE Dress of the People who practise this Trade is generally made of thick Flannel, which
being

being once wet, and the Water warm'd by the Heat of the Body, they afterwards scarce feel any Cold from moving about in the Water; because the warm Water, lodged next the Skin, will always keep the same Place: Just as when a Man's Cloaths are warm on his Back, he is not chill'd by the Blasts that visit him from without.

THOSE who go down in this Machine generally for some Time complain of a Pain in their Ear; which is by some thought to proceed probably from the extraordinary Pressure of the Air condensed on the *Membrana Tympani*, or a fine Membrane covering the Cavity, or Drum of the Ear; which has a small Aperture, imagined by some Anatomists to be clos'd with a Valve on the hither Side. Within this Membrane there can only be common Air, (for the Circulation of the Blood in these Parts is very slow) and without it is Air considerably condens'd, whereby the said Valve is supposed to be depressed, and the Part being exceeding nervous, might consequently create in the Patient a great deal of Pain. But when the Condensation of the external Air becomes strong enough to push down this Valve, the Pain then ceases, and the Patient recovers his former Hearing.

WHETHER there be any such Aperture in this Membrane, is not very certain, nor is it of any great consequence to the present Point, since by the *Eustachian Duct* passing from the Mouth immediately to the Cavity of the inner Ear, there is as free a Communication as can be expected

pected thro' so small a Canal. And hence it is observable, that such Persons as are hard of Hearing, when they are more than ordinarily attentive, are very apt to open their Mouths, that they may thereby catch as many of the Rays of Sound as they can, in order to assist their Hearing. The Trouble therefore that the Divers feel at first in the Ear, proceeds more probably from some Difficulty the Air may find in working itself, on the first Compressure, through the *Eustachian Tube*; and their growing easy afterwards, may arise from its taking afterwards the due Effect, and restoring the Equilibrium interrupted in that Part.

HOWEVER that be, one of these Divers imagining himself more cunning than the rest, thought to keep away the Ear-ach, by stopping his Ears full of chew'd Paper; but he fail'd in his Expectation: For as the Pressure increased, the Membrane was not only pressed as before, but the Wad of Paper was depressed along with it; so that the Surgeon had a great deal of Difficulty to get it out again.

BEFORE we quit this Subject, it will be proper to give a short Description of the Case, or Suit of Armour, made Use of for diving in shoal Water, where indeed Wrecks commonly lie, intended to defend the Head and Trunk of the Diver from the external Pressure, so that his Ribs may move, and he be able to fetch his Breath.

THE side Sketch of this Contrivance is given *Fig. 4. Plate 8.* and by *Fig. 3.* is represented the Diver therein equipp'd for Service, at Bottom of the Sea, let down thither by a Rope fastened round the Neck of the Copper Machine, which separates at the Waist to receive his Body, the two Parts of which are connected by Straps of Iron screw'd down, when the Diver is in, before and behind. Between the Place of the Right Arm and the Waist, is a Piece of Copper, which draws out of a Groove, to admit that Arm after the rest of the Body is in. This Groove is made Water-tight. On each Side of the Head-piece is fixed a Tube, to which several Lengths of stiff Leather Pipe, distended by Rings at proper Distances, may be screw'd occasionally, according to the Depth of Water, thro' which the Air is to be conveyed down from the Surface. In Front of the Head-piece is fixed a strong convex Glass, for sustaining the Pressure of the Water, so that the Operator may see what he is about. Just below his Elbows, where the Blood-vessels lie pretty deep, and under his Knees, are girt Leather Bags, fit to keep out Water; for tying which to the Copper Machine there is left a small Necking.

PEOPLE have been in this Machine forty Minutes at a Time, in a moderate Depth of Water, and have done Business upon a Wreck: But as there cannot be a free Circulation of Air thro' the Pipes of Conveyance, they are therefore obliged to use Bellows, and such like

Contrivances, to promote it. Provided the Business be of sufficient Importance to defray the Charge of the Bell, nothing answers the Intention so well.

Some Effects of the ATMOSPHERE'S
PRESSURE *on* ANIMAL *and* other
BODIES.

THE Alteration in the Air's Pressure upon our Bodies, is in general very sensibly felt by us. In clear serene Weather, when it acts with the greatest Weight, we usually find ourselves more vigorous, chearful and alert: In foul and close Weather, when the Air is more light, we are most commonly supine, dull, and languid.

In the former Case, the Fibres of our Flesh are braced up well, and made very tense, and of consequence the Channels of the circulating Fluids must be contracted by the greater accidental outward Pressure, aptly compared to a general Bandage on the Body; whence they must move, in equal Times, with more Velocity than when the Coats of the Vessels, for want of a proper Pressure, are distended and relaxed. And that this is the Case, appears in Part from an overstrain'd Limb's receiving immediate Strength and Relief from being bound up.

THE Lunaticks are a notable Instance of the Change of Weight in the Air. At New and Full

Full of the Moon, when her Attraction, in Conjunction with that of the Sun, raises the grosser Fluids in the Tides, it also generally causes an Alteration in the Gravity of the Air and Weather, shewn often by the Barometer; whence the Blood of these People is made to circulate with an accelerated Force, and then they become extraordinarily affected.

THE Old and Infirm are so many sensitive Barometers, and are generally very early in the Notices they give of the Alterations of the Weight of the Air, and consequently of the Weather. Rheumatisms, Gouts, Aches, Megrims, Shooting of Corns, and the like, are with them certain Indications of Rains, Snows and Storms. Nor are the Young and Healthful wholly insensible of these Changes, tho' the whole Texture of their constitutional System of Fibres be in fine Order, replete with Juices, tense and elastic; whereas those of the Antient are thro' Age and long Use become more dry and sapless, hard, tough, unpliant, and wanting of Spring. The Sufferings therefore of these are always greater, from this accidental Difference of Pressure, than the other, and are doubtless proportionable to their Complaints.

THO' the Pressure of the Air be sufficient to produce the great Effects before-mentioned; yet is the Force thereof sustained by temper'd Clay, thin Glass, and the most tender Bodies, without any Alteration in their Figure at all, merely from their being equally press'd thereby on every

Side:

Side: But no sooner can this Pressure be abated on one Hand, or increas'd on the other, than a sensible Change will immediately follow.

OUR Receivers in general, when they are first set on the Pump, press it only with their absolute Weight; but if the internal Air, by a Turn or two of the Winch, be attenuated, its Pressure on their Surface will cause them to adhere to the Plate, so as not easily to be separated from it. The Cause is plain.

A Receiver being placed on the Leather, the Air within, as well as that without, lies under equal Degrees of Compressure, and like a Multitude of little Springs, wound up or bent as many different Ways, supports the Weight of the upper Air. This inferior Air resists, and in its turn represses the inner Surface of the Receiver, and the Leather whereon it stands, with a Force just equal to that exerted by the Atmosphere on the Out-side of the Receiver and the Pump; whence proceeds a perfect Equilibrium between them. But we no sooner give one Stroke of the Piston, and extract Part of the inward Air, but that Equilibrium ceases; and as the Exhaustion is carried on, or continued, the growing Pressure of the one, and the decreasing Resistance of the other, make the Difference at length very notable; and such as will be extremely sensible to the Hand of a Person covering a small Receiver, two Inches over, open at both Ends, whilst gradually exhausted of its Air.

ANOTHER

ANOTHER remarkable Effect, produced by the different Pressures of the internal and external Air, may be observed on exhausting a square Bottle of its Air. This will be best done under a Receiver. The Phial is to have a Leather Valve so disposed as to suffer the Air to pass out freely during the Operation, but not to let it enter the Bottle again when it comes again to be admitted into the Receiver; the Pressure whereof will immediately squeeze the Bottle to Atoms.

IT may here be remarked, that flat Bodies are not so able to resist Pressure as are the round of equal Thickness; because all the Parts of these are disposed as in an Arch, and so sustain each other in a much better Manner than is possible for Bodies of any other Shape.

ANOTHER Instance of the Inequality of this Pressure, may be given, by increasing it within a Bladder, fastened at the End of an injecting Syringe, into which, by repeated Strokes, let a Quantity of Air be successively thrown. When the Power of the Spring is such, that the Weight of the Air of common Density without, and the Cohesion of the Parts of the Bladder become jointly unequal thereto, this Membrane will burst, and the inclosed Fluid will then get loose and shake the adjacent Air so as to affect our Nerves perhaps with the Sensation ordinarily called a Noise.

THE

THIS Experiment will also intimate to us the surprizing Effects fluid Bodies produce, in dilating Cavities, when push'd thro' small Channels. In this Case the Particles of Air thrust into the Bladder with a pretty good Force, insinuate themselves, and act as does a driven Wedge in dividing a hard Body. Which too is commonly the Case, it may be observed, in such Apoplexies as are fatal. Some of the small Blood-vessels break in the Head, and, in the Course of the Circulation, repeated Pushes being made through the fractur'd Pipe, the Brain at length comes to be so compress'd by the extravasated Blood, as to be no longer able to perform the due Secretions of the animal Spirits, whence immediate Death ensues.

A Stream of Air driven thro' a small Channel, will both raise and sustain a considerable Weight; and the smaller the Hole, the greater will be the Effect in a reciprocal Time. An easy Blast from the Lungs will raise about seven Pounds; but the Breath of a stout Person, blowing with all his Might, above twenty Pounds.

ONE large Bladder blown, may raise a Weight as high as several small ones; but the necessary Expence of Breath for this Purpose, in either Case, will be very different. For Instance; two Badders similar in Figure, but of half the Diameter of a large one (since Spheres are geometrically demonstrable to be in Content proportionable

portionable to the Cubes of their Diameters) will require but a quarter of the Breath to distend them, as will the greater; and yet will they jointly act in a quarter of the Time, and produce a proportionable Part of the Effect. This Experiment is commonly apply'd to the Explication of muscular Motion, and is represented *Fig. 5. Plate 8.*

On MUSCULAR MOTION.

THE Muscles of the Body, in general, are those Flakes of Flesh which appear when the common Teguments of the Body are removed. They cover the Bones, and not only conduce to the Comeliness of the animal Figure, but are so many moving Powers, by which a very great Number of distinct Motions may be made, differing from each other in their Forces, Directions, and various Effects.

OF the Muscles, some are round, some oblong, some flat, and others circular, some are simple, but most of them compound. The simple Muscles ordinarily consist of a Belly, red and fleshy, and generally of a Pair of Tendons placed at the Extremities, white and of a closer Contexture; both Parts whereof seem to be no other than Bundles of parallel Fibres, divisible with Care to a great Degree of Fineness; the minutest Sub-division whereof, or Fibril, seems to be a Muscle in Miniature, and to have its
Belly

Belly and two Tendons like the Muscle itself. Not but that some of the Muscles, and consequently their Fibres, have but one Tendon, being in that Case fleshy only at the other End:

THE compound Muscles have their different Series of Fibres; not parallel (tho' the Fibres that severally constitute them are so) but often inclined, and lying in different Directions to each other, and are, as well as all the rest, curiously adapted to the Purpose they are designed to execute.

THE Tendons are, for the generality, inserted into two of the Bones; one fixed, the other moveable: The first is termed its Origine; the second its Insertion.

As the Muscles contract, they draw the moveable Bone or Part, this way or that, according to the Direction of the Fibres of which they are composed; and as they diminish in Length, their Bellies are observed to increase in Thickness, tho' the Muscle itself enlarges not its Dimensions; but its Bulk is, on Experiment, found to be rather less. And this has been made evident, upon a lusty and muscular Person's moving and clasping his Fingers, when his Hand and Arm were curiously inclosed in a glass Vessel filled with Water, having a small Tube inserted in the upper Part, that so, by the Rise or Abatement of the Water therein, this Matter might be critically examined.

THE Veins, Arteries and Nerves (the two first of which being the Channels which conduct the Blood to and from the Heart, the Source of Life; the other being the Conveyance of the animal Spirits from the Seat of Perception, the Brain) are divided, branched and universally distributed all over the Muscles; since no one Point of the Flesh can be prick'd, but Blood will thence follow, and Sensation there be raised.

NOW the Action of a Muscle seems wholly to depend on the Non-obstruction of the Nerves: For if the Nerve of any Muscle be tied, the Muscle immediately ceases to act; and if it be cut thro', it does so for ever. Muscular Motion must therefore be effected by some Agency, communicated by the Nerves to the moving Part.

IT has been also generally received, that the same Effect will happen on tying or cutting the chief Artery of a Muscle; but this has been found not to succeed, when try'd on a Dog, unless the *Aorta* or principal Artery of the whole Body was tied. For the ingenious Dr. LANGRISH informs us, that he has tied up, and below the Ligature divided, four large Arteries of a Spaniel, who found no Sort of Defect or Inconvenience in his Muscles from the Operation when his Wounds were well: By which Time indeed the lateral Communication of the neighbouring Arteries might possibly be so enlarged, as from those Arteries to supply the Muscles hinted at with a free
Influx

Influx of arterial Blood, after their own Vessels had been destroy'd ; and which always must happen, we know, in such Subjects as survive the Loss of a Limb.

THE Manner in which the Learned have generally conceiv'd muscular Motion to be performed, is from the progressive Motion of the nervous Juice, increased and on Occasions forwarded by the Determination of the Will, to a certain Part, in an undulating Manner. And the muscular Fibres, open to this Influx, receiving thereupon a larger Quantity of the nervous Fluid, grow more turgid, and cause a Contraction, which the continued Circulation of the Blood and other Juices assists and promotes, till the intended Motion is brought about and executed. And what favours this Conjecture is, the Contraction of a dead Muscle, which is always raised by the Injection of Liquors.

THIS must be confess'd a plausible way of solving this very difficult Phenomenon ; but when we consider how great and surprising Things are done by People in a Fright ; when the Muscles act almost instantaneously with the very Apprehension of Danger, without any Reflection made, or seeming Action of the Will perform'd at all ; it may be doubted whether these sudden and prodigious Effects are brought about in the steady, uniform and regular Way before proposed.

BESIDES 'tis well known, that muscular Motion in the Heart of the Eel, the Salmon, and Frog, will continue after they have been a long Time, several Hours perhaps, out of the Body; and when their Pulsation has even then ceas'd, that it will be resumed and repeated, on their being warm'd a-new, or pricked by a Needle. But the most remarkable Phænomenon of this kind is, the Twisting and Twining of the Viper, which will continue for many Hours after the Head, Heart, Entrails and Skin are taken from it. Nor is it in the least satisfactory to alledge, as is commonly done, that the Fluids in these Animals are more viscid, and are therefore longer retained in the Vessels of these Creatures than in those of others, to produce the said Effect, after all the Conveyances of the animal Spirits are intercepted, and their very Source is destroyed.

WE cannot therefore but own, that the Business of muscular Motion is not yet so well understood as 'tis hoped it may hereafter be, when the Industry of After-ages, assisted by the Observations of the foregoing, shall have made a greater Progress therein.

IN Favour of the present Opinions concerning it, however, and to shew that Muscular Motion is at least begun by an Impulse made on the Fluid contain'd in the Nerves, it may be observed, that if a Frog in Summer-time be taken when that Animal is vigorous and suspended by

the Fore-paws between two Pillars, and his Head cut off with a Pair of Scissars. The Body and Limbs will both during that Operation and after, remain quiet and unconvulsed. If a small Probe, somewhat blunt at the End, be then push'd gently down the Cavity of the *Vertebra* of the Neck, so as to touch the spinal Marrow (which is no other than the Prolongation of the general Collection of the Nerves, issuing from the Brain itself) the Hinder-legs, which before hung loose, and as if the Creature were really dead, will on such Pressure, immediately suffer a very strong and complete Contraction. And if the Probe be applied in like Manner to the *Medulla oblongata*, in the dissevered Head, 'twill cause the Eyes to move, and sometimes the Mouth to open. And this may be several times repeated on the same Subject, provided Time be given for the Restoration of the Blood and Juices, in that languid State of Circulation, if it deserves that Name, which was thrown out of the Muscles in the last Contraction; but it must be expected every time to be weaker and weaker.

It may here be remarked, that extreme Cold is always a considerable Hindrance to muscular Motion; a Swelling from extravasated Humours, which fill the Interstices, and prevent the Corrugation and Contraction of the Fibres, does the same. Great Tremors, such as those of the musical Strings, which vibrate with a prodigious Degree of Swiftmess, and when long play'd on, very commonly affect the Ends of the Fingers of the Performer with Numbness.

Laying hold on the lower Part of a springing Piece of Metal, when filed in a Vice, will very soon produce the same Effect; as also does the Touch of the *Torpedo*, a Fish which has a Pair of Muscles on his Back, composed of very large and stiff Fibres, which being touched, he naturally moves to and fro with such Swiftneſs, that it numbs the Hand, and immediately impairs muscular Motion therein. It may then be a Question, whether muscular Motion be not produced by the Nerves alone; ſince whenever they are diſconcerted, diſturbed or obſtructed, by certain Accidents, a Blow on the Head perchance, or the very Apprehenſion of great and eminent Danger, ſuch eſpecially as produces Amazement and Diſmay, will on Experience, we ſee, effectually cauſe all muscular Motion to ceaſe.

BORELLI, and other ingenuous Author after him, by the Help of a fine Imagination, have conjectur'd, that the long parallel Fibres which compoſe a Muſcle, were, beſides being together incloſed in the common Membrane of the Muſcle, connected alſo by tranſverſe Fibres, croſſing the longitudinal ones, and dividing them at very ſmall Diſtances, into a great Number of ſmall Cells, Veſicles or Bladders; which perhaps may be found ſomewhat more than an Hypotheſis, ſince the Fibres in the tranſparent Membranes of a Frog's Foot, have by the ſolar Microſcope been obſerved to reſemble collateral Rows of ſmall Pearls. And this Way have they endeavoured to explain the Mechanism of muscular Motion. The Thought

is philosophical, and pretty enough, which they thus pursue.

A Bladder, void of Air and flaccid, they consider as a Muscle in its utmost Elongation ; when inflated, as a Muscle contracted. Being empty, it may be perhaps eight or nine Inches long, and then barely suspends the Weight *A*, *Fig. 5. Plate 8.* Being replete with Air (blown thro' the Pipe *B*, the End of which within is covered with a Valve, to ease the Lungs, and prevent the Return of the Air when the blowing ceases) it will raise the Weight to a certain Height. The upper and nether Parts of the Bladder represent the Head and Tail of the Muscle, and the Weight intimates the Force wherewith it acts.

ACCORDING to *Fig. 5. Plate 8.* we know that by one Bandage put about the Middle of our inflated Bladder, as at *C*, the Weight will move in a quarter of the Time, and with a quarter of the Breath requisite to fill the Cavity of the whole without a Ligature, and that a fourth Part of the Effect will be produced thereby. Now should the Bladder, thus divided, be again subdivided with Bandages at *D* and *E*, the whole will become a String of small Bladders, each being a fourth of the Diameter of the first, which being blown up, will raise a certain Weight in a sixteenth Part of the Room and Time that the large one will.

AND 'tis reasonable to believe, that if one Bladder of a certain Content will when inflat-

ed raise a Weight to a certain Height, two communicating will produce double the Effect, and so forward. And was a Chain of Bladders, thus circumstanced, equal in Bulk, and like in Figure, joined together, the Space through which the Weight would be raised by them, must be proportionable to their Number, or, which is the same Thing, to the Length of the String. And if a determined Weight may be raised a certain Space by one Bladder, or one String of Bladders, double the Weight will be raised by two such; and consequently the Weight raised by a Muscle will be in Proportion to the Number of its Fibres, *viz.* its Thickness: And the absolute Strength of one Muscle is to that of another as is its Weight or Bulk.

WAS it not for the forementioned Contrivance, or something equivalent, in the Construction of the Muscles, all animal Motion must be exceeding deliberate and slow, and a Snail or Tortoise might be reckoned, and perhaps justly, very nimble Creatures.

*On the HEART, and CIRCULATION of
the BLOOD.*

MUSCULAR Motion in general is voluntary, it being in the Will and Choice of an Animal, in Health and uncon-
vulsed, whether he will move any Part of his Body, or whether he will give it this or that Direction or not. But the Heart is a compound

Muscle

Muscle exempted from that Law, which during Life, whether we will or not, incessantly moves, and at every Pulse receives Blood from the Veins, which it again throws out along the Arteries, to the very Extremities of the Body, where the Arteries divide, either into lymphatic Vessels, into excretory Ducts, or capillary Veins, too fine for Sight. Here the Blood and Juices are strain'd, absorbed, and again collected by the smaller Ramifications of the Veins, thro' which they are again conducted back to the Heart, where the same Process being repeated, the animal System is thus preserved often a Hundred Years. So curious a Piece of Pump-work cannot but deserve a little of our Attention.

THE Heart lies almost transversely on the Diaphragm, hereafter described, *Page 211*, the greatest Part of it is found in the left Cavity of the Thorax or Chest, wherein it is suspended at Liberty by the Blood-vessels, with which alone it is connected. Its Basis is toward the right, and its *Apex* or Point inclines to the Left, where usually we feel it beat. 'Tis inclosed within a fixed Bag, called the *Pericardium*, having in it a serous Liquor, in which it floats : to the end that its Fibres might not only be kept always warm, moist and supple ; but also that by performing its Functions in a dense Fluid, its Motions might be rendered thereby more regular and steady,

It is of a conical Figure, and its fleshy or muscular Parts consist of several different Orders

ders of Fibres, so directed and disposed as either to contract or dilate it, which they do by turns, regularly, and without Intermiffion, as has been faid, from the very Beginning to the End of Life.

IN the Contraction of the Heart, the Point is drawn up a little towards the Bafe; in its Dilatation or Reftitution, the *Apex* returns to its natural Situation. The firft of thefe is by Anatomifts termed the *Syftole*, the latter the *Diaftole* of the Heart.

WITHIN the Heart are two Cavities, termed Ventricles. They are divided by a ftrong *Septum* or Partition, the Place and internal Direction whereof is marked on its Surface, *Fig. 6. Plate 8.* by the white Line *E P.* At the Entrance of either Ventricle is a hollow Appendix, a kind of Bag of a loofer Texture than the Heart. Thefe are called the Auricles, with which the Ventricles, thro' Valves of an admirable Texture and Difpofition, refpectively communicate. The right Auricle is there denoted by *B*, into which Blood is admitted from the *Vena Cava* whenever the Heart contracts; this large Channel, both afcending from the Parts below, and defcending from thofe above, marked *AA*, conducts the Blood, collected by the leffer Veins from all Parts of the Body to the Heart, in which it difcharges its Contents at *N*, where is an excellent Contrivance, which hinders the direct Shock of the two confluent Streams, as in the Figure is exprefs'd; tho' this

is much more perceptible in Brutes than human Subjects. The Place of the right Ventricle, marked *Q*, is between *C* and the *Septum Cordis*; into which the Blood last received by the contiguous Auricle is admitted whenever the Heart dilates. *D* is the Section of the pulmonary Artery, whereby the Blood is thrown from the right Ventricle into the Lungs, which are spread without the *Pericardium* on either Side of the Chest, and being divided into several Lobes, *viz.* three on the right and two on the left, when inflated, they wholly fill the *Thorax*. These, by Construction and Texture, seem to be a vast Collection of small Vessels, thro' which the Blood being push'd with some Force and Rapidity, becomes attenuated, and there meeting with the cool Air continually inspired, is thereby rectified, refreshed, and is then immediately gathered up by the pulmonary Veins, the numberless Ramifications of which terminate in four Canals, conducting the Blood from the Lungs into the left Auricle of the Heart, in its *Systole* or Contraction. This Auricle is signified by *P*, and the Inlets of the pulmonary Veins thereinto by *R R*; two of which lying backwards, are in our Draught only prick'd.

AT the succeeding Restitution or *Diafsole* of the Heart, the Blood last received from the Lungs is admitted into the left Ventricle, the Place of which is between the *Septum* and the left Side of the Heart, denoted by *S*; and by the following Contraction it is thence thrown into the great Artery, or the *Aorta*, marked *GO*;

GO; from the several Branchings or Ramifications whereof it is distributed to every Part of the Body respectively. *H, I, K, L, M,* lead it away to the Head, Arms, &c. and from the Continuation of GO (carried and directed downwards, to moderate perhaps the prodigious Force of the Heart) the Trunk and lower Parts of the Body are supplied with arterial Blood, by distinct Canals branched off here and there, to the very Extremities of the Body, at every *Systole* or Contraction thereof.

It must not however be imagined, that one and the same, or a single Portion of Blood, received at first from the *Vena Cava*, is thence circulated alone to the *Aorta*, by the six distinct Steps or Stages beforementioned. But as a constant Supply is wanted for the continued Purposes of Life, the Circulation is to be supposed continual, and that at every Motion of the Heart whether in its Contraction or Restitution, all the four Cavities are more or less employed, *viz.* In the Contraction both Auricles not only together receive Blood from the Veins with which they respectively communicate, but the two Ventricles at the same Time also expel into their respective Arteries the Blood which they had but just before received, in the Restitution of the Heart, from the Auricles, which are then only empty'd into them: So that whenever the Ventricles dilate, the Auricles contract, and the contrary, by the alternate, constant, uniform, and regular Motion of the Heart.

THE

THE Arteries are strong conical Ducts, larger towards the Heart, and less towards the Extremities of the Body, of an elastick Nature, and which dilate when the Heart pushes Blood into them (this strictly is called its Pulse) and contract immediately when that Push is discontinued. The Veins, like the Arteries, are also Tubes of a conical Figure, and their Office is to collect and return the Blood in an even Stream, as has been said, to the Heart, from the Extremities, whither it had been carried by the Arteries.

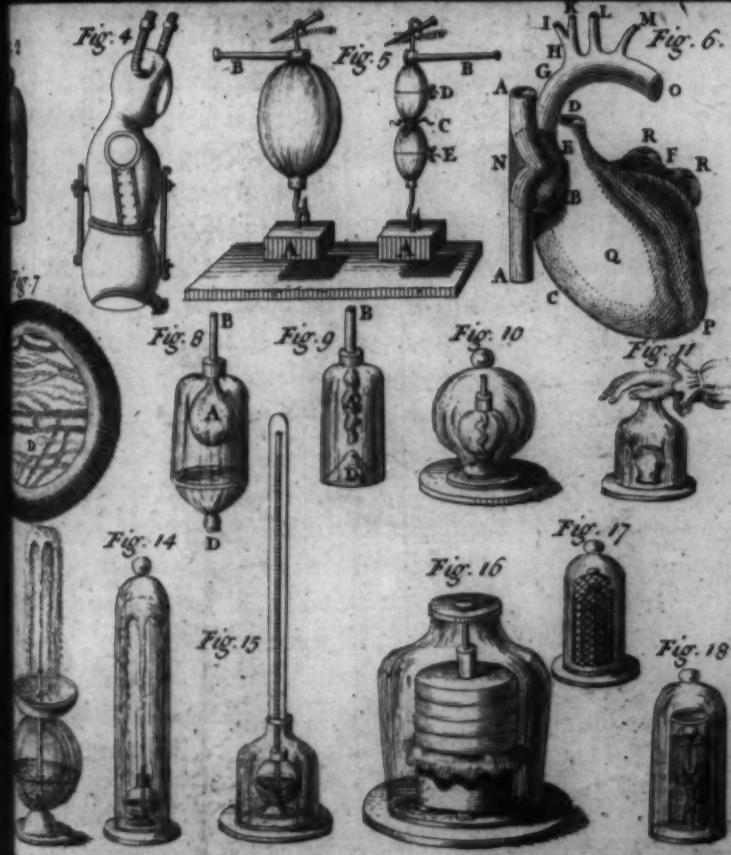
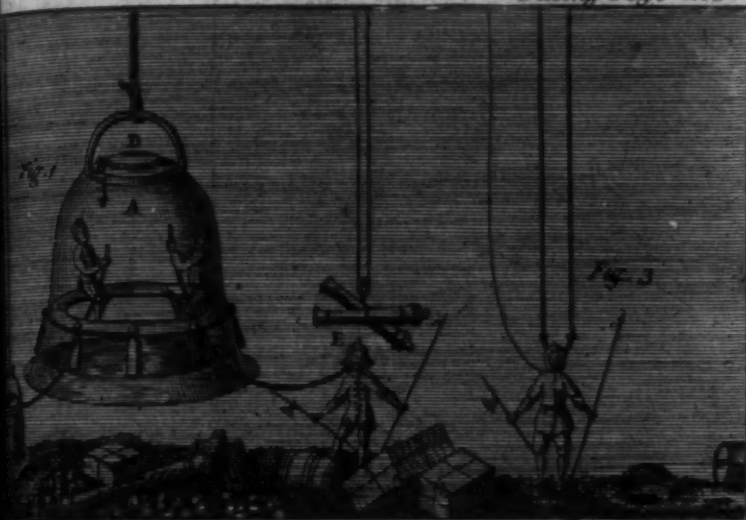
IN this, as indeed throughout the Animal System, most admirable seems the Artifice of Nature. The Arteries are found conical as they leave the Heart; the Push thereby made, is in part then moderated by the Reflexions of the Fluid necessarily produced by the inclined Sides of those Canals, to the End that Time and Opportunity may be thereby given to the several Ramifications and Outlets distributed all along the *Aorta*, many of which are very small, to gather up such Part of the fluid Stream as may be wanting for the Nutrition of the Parts to which they severally belong: Whereas the Veins are observed always to enlarge themselves as they approach toward the Heart; that the returning Stream, when the impelling Force is greatly abated and almost spent, may, by passing thro' a Tube filled with a Fluid only, meet less Resistance than must needs have been found from a continued Friction along the Sides even of cylindric Vessels.

THAT

THAT this successive Circulation of the Blood is no Chimera, may be evident from observing the Course of it in the transparent Membranes of Animals, with the Microscope; whereby the Globules of Blood may be distinctly seen in the Arteries to flow with great Velocity one Way, and in the Veins the contrary, with greater Moderation.

BESIDES which, whenever an Animal is opened alive, if a Ligature be made on an Artery, it always swells between that and the Heart, its Beatings become a great deal stronger, and the Blood spouts out of it with a surprising Force, if an Opening be therein made: Whereas when a Vein in that Case is ty'd, the Part which is between the Ligature and the Heart is found empty, lax, and yields no Blood when opened.

THE Section of the Arteries is always smaller than that of the Veins; and of consequence the equal Stream, being in these more confined, is observed to be as mention'd more rapid in them. *Fig. 7. Plate 8.* is the Representation of the Veins and Arteries filled with the Globules of the Blood circulating in one of these Animals, the Figure of which is drawn round, because the Spot of reflected Light, by which these Things are to be observed, exhibits such a View. The Places marked *DDD*, are those where the Veins and Arteries were seen visibly to communicate.



THE Truth of it will also farther appear from observing the Veins on the Back of the Hand, if the Skin be clear. These Tubes are furnished at fit Distances by femilunar Valves, which on proper Occasions shut downwards, or towards the Extremities, to take the Weight of the ascending Fluid from off the Trunk of the Veins laterally, which would otherwise be found inconvenient, and give the Body some Pain. And the immediate Relief and Ease we find on our lying down, shews, that the Abatement of this Pressure, even with these Contrivances, is not inconsiderable.

STROKE then your Finger down toward the Knuckles pretty hard, and 'tis odds but you'll pass by some or other of these Valves; the consequence of which will be, that the Vein above the Valve will be full of Blood, and between it and your Finger empty: on removing whereof it will however fill immediately, and the Circulation will appear then to proceed as usual. Or else, putting down a Finger in the same Place to stop the Course of the Circulation in the Vein, stroke the Blood lying between your Finger and the Valve upward, the same thing will happen. In order therefore to breathe a Vein, a Bandage is to be made in any convenient Part; and the Course of the Blood continually forwarded from the Arteries into the Veins, being thereby partly stopped, the Vein will swell below the Fillet, never above it, unless in the Neck: Which also plainly intimates
the

208 *The Motion of FLUIDS,*

the Course of the venal Blood to be from the Extremities of the Body toward the Heart directly.

*Of DIGESTION, SANGUIFICATION,
and NUTRITION.*

HAVING dipped thus far into the animal Oeconomy, the Curious will not be displeased with a short Account of Sanguification, or the Manner in which a Digestion of the Aliments received into the Stomach, furnishes Matter to repair the Decays of Nature, and supply the Body with necessary Nutriment and Strength.

SOLID Food being taken in by the Mouth, reduced to a certain Degree of Fineness by the Teeth, and at the same time mixed with the Spittle (a limpid Humour secreted or separated from the Blood by particular Glands for that Purpose) is transmitted thro' the Gullet, which is a Passage behind the Wind-pipe leading into the Stomach, lying beneath the Midriff, and situated chiefly on the left Side of the Abdomen or lower Belly, where the Parts are farther opened and divided by the Juices secreted by the Glands of the Stomach, and by what we drink.

HENCE it is gradually pass'd into the small Guts; where meeting with two other Secretions from the Blood, namely the Bile or Gall, and the

the pancreatic Juice, the one contained in a Bag annexed to the Liver, and the other supply'd from a particular Gland, it is elaborated by the vermicular or worm-like Motion of the small Guts, also involuntary, continually promoted also by the Act of Inspiration and Expiration, into a still softer Substance.

FROM the small Guts, the finer Parts of the Aliments, called the Chyle, are collected and absorb'd by the lacteal Veins, opening into them, and by these are transmitted to the Receptacle of the Chyle, a small Knot or Bag placed near the Loins; being forwarded thither, not only by the continual vermicular Motion of the Guts abovementioned, but it is assisted in its Progress onward also by the Power of the Attraction of Cohesion in the lacteal Veins themselves, which are exceeding small Tubes, and scarcely ever visible in cold Subjects.

HENCE in the Progress of Digestion it is again pushed upward along the thoracic Duct, also small, as high as the Shoulder; being forwarded in its Ascent thither by the continual Beating of the great Artery, or the *Aorta*, near which it is for that Purpose very rightly placed.

IT is thence emptied into the left subclavian Vein; after which it proceeds regularly with the Mass of Blood to the Heart, and thenceforward continues to circulate with it, till by Degrees it becomes assimilated first, then perfect Blood, and so helps to supply from time to time the

natural Secretions, to nourish the Parts, to serve the Uses, and repair the Decays of the animal System.

AND truly admirable is the Disposition of Parts in this whole Machine ; admirable the Execution of all its Functions ; the Impulse given from one Part always begetting Motion in another, that on the next, and so on thro' the whole Body. From the Circulation of the Blood, the very Being and perhaps the Motion of the animal Spirits are derived ; from the Influence of those Spirits over the muscular Fibres, very probably arises all muscular Motion ; from muscular Motion the Circulation of the Fluids is maintained, in a great measure otherwise stagnant ; and from this Circulation all the necessary Secretions for the Continuance of Life are made, and the Vessels of the Body are thereby kept supple, and preserved in a fit Disposition and a Readiness for Motion and Use.

On ANIMAL INSPIRATION and EXPIRATION.

THE Business of Respiration, wherein the Air is principally concerned, will properly come next under Consideration. And this consists of two Parts, Inspiration, whereby Air is taken into the Lungs ; and Expiration, whereby it is thrust out of them. These are in some measure performed by the Power of the intercostal Muscles acting on the Ribs, disposed in
Form

Form of a semicircular Arch, and articulated with the *Vertebræ* of the Back behind, and connected with the *Sternum* before; which are the two Pivots or Centres on which they are made to move.

THE Diaphragm or Midriff is a Partition drawn quite cross the Body, intirely dividing the Thorax or Chest, containing the Heart and Lungs, from the Abdomen or Belly, wherein the Liver, Stomach, Guts, Spleen and Bladder are contained. This is a Muscle whose central Parts are tendinous; the rest is fleshy, having its Fibres disposed like Rays all round a Center. By its Disposition and Structure it is capable of Expansion, whereby it becomes concave below; and of Contraction, whereby it becomes flat, which it alternately does, and thereby becomes the principal Agent in the Article of Breathing.

IN Inspiration, the Ribs being rais'd as above, the Diaphragm is drawn up, and made flat; by the Complation whereof the Cavity of the Thorax or Chest is enlarged, and the Air therein included, having no sort of Communication with the outward Air, is thereupon inclined to dilate: To prevent which, and preserve the Equilibrium, the Air from without of course presses down the Wind-pipe, and swells the Lungs instead.

IN Expiration the Ribs fall; the Diaphragm, against which the Liver, Stomach and Intestines in the Abdomen also press, again expands,

pands, becomes concave, and contracts the Capacity of the Thorax; upon which the Air therein inclosed, being somewhat compressed, bears against the Surface of the Lungs, causes them to contract, whence the Animal is made to expire; and this is repeated every time we draw Breath: In doing whereof the Lungs are perfectly passive, and play only in consequence of the muscular Motion before described, assisted by the Action and Influence of the Atmosphere upon them.

THE Disposition of the Lungs in the Business of Respiration is well represented by the Machine *Fig. 8. Plate 8.* wherein *A* is a blown Bladder tied fast on the End of a Pipe *B*, denoting the Wind-pipe, and communicating with the outward Air. *D* is a lax or loose Bladder, fixed to the Bottom of the Glass, and is in lieu of the Diaphragm. The Air between the two Bladders in the Glass intimates that supposed to be pent up in the Cavity of the Thorax. This artificial Diaphragm being by the Hand pushed inwards, the Air inclosed in the Glass will be condensed, and bearing against the Surface of the artificial Lungs, will compress them so as to force out their inward Air; as it in real Expiration happens: And again, being pulled outward, the contrary Effect will appear, as in real Inspiration it is. Both Actions are represented by *Fig. 8* and *9. Plate 8.*

WHENEVER any Animal, not of the amphibious Kind; or one not living indifferently either

either by Land or Water, or Insects, are in the pneumatick Engine deprived of their outward Air, the internal Air, in the Chest confined, will naturally dilate, and for Want of a Counterpoise to support and keep the Lungs distended, these will contract; upon which the Blood-vessels thereof will be all compressed and closed, and the Circulation being thus stopped, the Animal will immediately fall into Convulsions; and without speedy Relief by the Admission of fresh Air, to counterbalance the said Pressure on the Lungs, certain Death ensues.

THE Manner in which this is done, is aptly expressed by *Fig. 10. Plate 8.* from which if the external Air, and with it the communicating Air contained within the Bladder, be exhausted, that confin'd between the Membrane and the Bottle will by its Spring dilate, and thrust the Bladder, here also representing the Lungs, on a Heap:

It may moreover be here remarked, that there is a natural Contractility in all muscular Fibres, or a Propensity to contract themselves; and that whenever they are freed from the Counter-action of some adequate Force, which, in the present Case, the Air constantly received by the Wind-pipe always proves, that alone might be sufficient to produce the Effect here proposed.

It may also be farther remarked; That if any Animal has never drawn Breath, the Lungs, being in that Case, specifically heavier, will sink

in Water: But after it has breathed, the Vesicles of the Lungs being distended with admitted Air, will always swim. By this Method the Surgeon can positively say, whether an Infant suspected of being suffocated, was still-born or not.

On ANIMAL SUCTION.

A Creature not an Hour old is Master of this needful Piece of Philosophy and the Skill and Dexterity exerted, even by those of the mute Creation as soon as they drop, is an Instance of preserving Providence not enough to be admired. Lest a wrong Idea however might be affixed to a good and useful Word, it may be proper first to settle what by Suction is really to be understood.

In order to this, we may take a Cupping-glass, put it, the Mouth downwards, under a Receiver open at Top; but which may on Occasion be closed by the Hand, as *Fig. 11. Plate 8.* Exhaust them thus together, and on shaking the Pump, the under one will be seen to freely move, the other, pressed by the Weight of the Atmosphere above, will adhere to the Leather fast enough.

Now were our Glasses fixed down to the Plate of the Pump by any Power of Suction they would, in this Instance, both be so; which is contrary to Fact. However, if we catch away the Hand from the Hole of the Receiver

in this Circumstance, and suddenly admit the Air upon the Cupping-glass from above, that Machine will then be fixed down by the Weight of the Atmosphere, thrown upon it all at once, and the Receiver will be at full Liberty: Which to a Demonstration proves, that it is no Property in Suction, but the Air's Pressure only, by which the grosser Fluids are made to move. And this is also farther evinced, by the Experiment mentioned in the *Hydrostaticks*, Page 48. to which we refer.

AN Animal therefore, upon applying his Mouth to suck, does no more than distend his Chest, much as in the Case of Inspiration, whereby, strictly speaking, the Air is drawn, or sucked into the Lungs; at which Time, the rarer Air within, not being a Counterpoise to the denser Air without, the Water from the Spring, the Milk from the Breast, and the like, are forced into the Mouth: Whence again, by working the Pump-work of the Parts of the Throat, qualified to act on that Occasion as a double Valve, or one that will occasionally both suck and force, the Rise of the Fluids first into the Mouth, and then their Descent into the Stomach, is alternately promoted.

*On the SPRING or ELASTICITY of
the AIR.*

THE Pressure of the Air having been already undeniably demonstrated, let us next consider its Elasticity.

As the Air is a Mass of fluid Matter, generally yeilding to all Impressions, it may be easily condensed, and by Injection from a forcing Syringe, be crouded into Vessels of Strength sufficient to bear the Force of such Compressure. In the Wind-gun, for Example, which is a Machine shap'd like a Fusil, into the Chamber whereof Air may be injected by a proper Syringe, till it is twenty times perhaps of the Strength and Tenour of our Atmosphere, and able to throw a Bullet, by its Spring, thro' a Board several times successively, whenever Part of it shall be let go, or suffered to rush forth, on the Fall of the Cock: But yet the aerial Particles, in the greatest Degree of Compressure possible, shall not be so wedged together, as to come to a general Contact: For that would entirely destroy their Spring; which in the Nature of Things is impossible to be done.

COMMON Air near the Earth, by the working of the pneumatick Engine only, and without any extraordinary Degree of Heat to heighten its Spring, may be very much dilated (according to Mr. BOYLE's Experiments, certainly thirteen thousand, and probably four times as much) yet shall its Parts even then not want for Spring, tho' it must be exceeding weak.

THE Expansion of the aerial Particles will be better understood, if with Mr. BOYLE we conceive them, fine as they are, and imperceptible to Sense, to be like so many little Watchsprings, coil'd round and contorted, but infinitely

nately more perfect ; since these are found to act every way, and every way alike, in a spherical Manner ; and by a certain Rotation round their Centres, beat each other out of their proper Spheres of Activity.

SIR ISAAC NEWTON, in his *Principia*, says ; *That if a Fluid consists of Particles repelling one another with a Force reciprocal to the Distance of their respective Centres, such Fluid will have a Spring reciprocal to the Space in which it shall be compressed* ; which is certainly applicable to the Air. For the component Particles of this Fluid endeavour to expand and recede from one another with a Force so great, that the greatest Compressure is not able to overpower it, or so to condense them, as to drive them within the Sphere of each other's Attraction, and prevent or overcome their Elasticity.

So that the more the Air is compressed, and its Density encreased, the more elastick still it is ; because the nearer its Particles are squeezed together, the more they repel, and endeavour to fly from, and avoid each other. And let the compressive Power be ever so great, or continue ever so long, the Moment it is removed they will expand and recede from one another with a Velocity proportionate to the Degree of the Compression ; that is, the Force, by which the Particles of the Air fly from each other, increases in the same Ratio as the Distance in which the Centres of the Particles are diminished ; or, in other Words, the repelling Force is inversely as this Distance.

THE Particles of Air are much compressed near the Earth by the incumbent Weight of the Atmosphere above, which being removed, they immediately evolve themselves, and extend what perhaps was but a Spherule at first, to a Sphere of large Dimensions; as will be evident from inverting a Bolt-head, or if you please a *Florence* Flask, almost full of Water, into a Jar, having little Water in it. For, on exhausting the ambient Air, which before buoyed it up therein, it will all gradually sink down into the Jar; and the small Portion of Air, which before possessed but a little Room, will dilate, on the sinking away of the Water, fill the whole Flask, and in the Course of Exhaustion, perhaps some of it may be seen also to rise and bubble thro' the Water thus all brought down into the Jar. This Experiment is represented *Fig. 12. Plate 8.*

As another visible Instance of this Spring, we may take a tight Vessel, as *Fig. 13. Plate 8.* and fill it about a quarter Part with Water; screw into it a Pipe, reaching nearly to the Bottom, into which afterwards inject a Quantity of Air, which at every Stroke of the Syringe will be forced thro' the Body of the Water, and being the lighter Fluid, will take Place above. The Spring of the Air thus injected will by Degrees become very considerable, bearing hard against the Top and Sides of the Vessel on one hand, and on the Surface of the Water on the other: So that upon opening the
Cock,

Cock, it will thereby be forced up in a very smart Jet; and when the Water is all pushed out and spent, the Air will follow in a vigorous Blast.

MUCH the same Effect might also be produced, by Air of the common Degree of Density, in rarefied Air, as will appear from making the Experiment on a fit Machine for the Purpose, by only exhausting Part of the Air from the Receiver; the Figure whereof is represented *Plate 8. Fig. 14.*

BUT certainly to determine what the natural Power of the Spring of the Air is near the Earth, put a Quantity of Quicksilver into a circular Phial. Screw a Tube, open at Top, and upwards of thirty-one Inches long, into its Neck. Place it under an Apparatus that may be exhausted. Which done, the Air pent within the Cavity of the Phial will expand, and by the Power of its Spring, raise the Mercury to the same Height, within a Trifle, as in the Gage-tube it does, from the Air's Pressure without: And it would raise it quite as high, but that the natural Spring of the Air, when Part of the Mercury comes thus to be thrust from the Phial into the Tube, by that Expansion must be somewhat weakened. Nor can the Force of the Air's general Spring, and its Pressure, be reasonably any other than equal; since the Action of the one, and the Re-action of the other, are according to the Laws of Nature always equal and contrary. This Experiment is represented, *Plate 8. Fig. 15.*

A notable Instance of the Power of this Spring, may also be given, in its raising a considerable Weight; which is to be done by tying up a Quantity of Air in a strong lax Bladder. Let this be either suspended in a larger Receiver, with the Weight at the End, as suppose that represented by *Fig. 5. Plate 8.* or for Convenience rather let it be thrust into a wooden Hoop, to confine and keep it from spreading side-ways. On this let the Weights be laid, as *Fig. 16. Plate 8.* Exhaust the Receiver of the ambient Air, and that inclosed will by its Expansion visibly raise the Weights with a great deal of Ease.

ANOTHER Evidence of the Power of this Spring may be had, by confining the Air within a square Phial, not over-strong, which when the Atmosphere's Pressure above is removed, will throw the Sides outwards. To preserve the Receiver in this Experiment from Damage, a small Wire Cage is commonly put over it, as in *Fig. 17. Plate 8.*

THE following is an entertaining Experiment made on the alternate Contraction and Expansion of the Air. This was before hinted in the *Hydrostaticks, Page 118.* and is here represented *Plate 8. Fig. 18.* Take a small glass hollow Image, that will swim in Water, having a Hole made into the Cavity at Foot. Put it into a Jar of Water, under a Receiver. Exhaust Part of the Air, and on admitting it suddenly again, Water will be thereby pressed into the Cavity, and filling it in good Measure, will make

make it probably specifically heavier than an equal Bulk of Water; then 'twill sink. This done, attenuate the Air in the Receiver a second Time; upon which, the Air remaining in the Body of the Image, will by dilating push forth a Part of the Water, causing it to emerge. And thus may it be made to rise or sink in that Fluid, as often as the Experiment is repeated, as at the Word of Command.

THE Use of the Air-vessels in Fish is something in the Way of the present Experiment. The Fins of these Creatures are not alone able to give them a due Command of Motion, in all Depths of Water; they have therefore a Bladder of Air within them, so disposed, that by contracting or dilating thereof by the Power of their Muscles, assisted by the Pressure from without, they can at all Times sink into the Deep, or rise to the Surface of the Water, with great Readiness and Ease. But when an Animal of this sort comes in a Jar of Water to be in *Vacuo*, the Air in the Vessel before said will so expand, as to keep him wholly above Water, whether he will or not, to his great Pain and Inconvenience.

FOR the same Reason, a Piece of soak'd Sponge, when first put into Water, will perhaps swim only near the Surface; but when the Air, on exhausting, has freed itself from many of the small Vesicles which it before possessed, and of which that Plant is full; and when, by a sudden Re-admission of the
Air

Air into the Receiver, Water is forced into them instead, 'twill then probably sink : But on repeating the Exhaustion, it will again rise ; unless there shall be no Air remaining in those Cells, to expand and make it once more specifically lighter than an equal Bulk of Water.

FOR a like Reason, Timber dug out of Bogs and other moist Places will seldom swim in Water ; the Particles whereof having by various Accidents, in a great Length of Time, wholly dislodged the Air from the Vacuities of the Wood. Whence it also appears, that even Wood itself is no otherwise comparatively lighter than Water, than as it has many Pores filled with Air, which is a Body many times lighter.

THERE is a small Quantity of Air commonly inclosed at the bigger End of an Egg, between the Duplicature of the Film that lines it, which being dilated by the Warmth of the Hen sitting, generally heaves up the Contents, and so contributes to the Formation and Production of the Chicken. This little Portion of Air, on opening the smaller End of the Shell, turning it down into a Jelly-glass, and exhausting the outward Air, will not only expand so as to separate the said Membrane from the Shell, to which it usually adheres, but will even thrust both White and Yolk quite thro' the Hole into the Glass ; which on re-admitting of the Air into the Receiver, will thence be made to retire, being forced by its Weight again into the Shell. The Expansion of this included Air will still be
more

more evident, if half the Shell be cut away, the Contents removed, and the Experiment repeated.

BEFORE this Subject is dismissed, the Description of *Hero's Fountain*, playing by the Spring of Air condensed by Means of a Stream of refluxent Water, will, 'tis hoped, not be unacceptable. *Fig. 1. Plate 9.* represents a tin Machine, consisting of two equal Vessels *A*, and *B*, both Air-tight, and communicating by the side Pipe, marked *C*. The Vessel *B* has a Pipe leading from the upper Basen of the Machine *E*, into which the Jet falls, quite thro' *A*, and reaching nearly to the Bottom of *B*. By Water poured in at *E*, as the Air has leave freely to escape thro' the Opening at *F*, *B* may thereby be charged half full, or more; which upon turning the Machine, will descend thro' *C*, and charge *A* in the like Proportion. The Pipe *C*, continued nearly to the Top, will also prevent the Return of the Water when the Machine is set again on its Basis. This done, *A* will be charged with part Water, part Air, and *B* will contain Air only. Then on pouring as much Water again in at *E*, as will fill the Tube; and the Weight of the Water contain'd between *E* and *D*, endeavouring to force its Way into *B*, the Air both in *A* and *B*, as they communicate, will be condensed in a certain Degree, and this pressing the Surface of the Fluid in *B*, the Jet will begin to play above thro' *F*, with a Force equal to the Difference of the Resistance of the common Air, into which it rises, and the Force of

of the denser Air in the Machine inclosed. And this Cause being all along uniformly continued by the constant descending of the Jet-water at *E*, the Effect will not cease, till *A* shall have parted with most of its Water, and then the condensed Air will follow it likewise thro' the Jetting-pipe *F*, as in a Blast.

The Manner of CUPPING.

THAT there is a Quantity of Air contained in the Flesh and Humours of the Body, will also appear in part from the Protuberance immediately rising on the Discharge of part of the Atmosphere's Weight in Cupping. In doing whereof, the Operator generally takes a small Glass close at Top, and holding it a little over the Flame of a Lamp, the common Air being heated, its Elasticity is thereby increased, and a Part of it is accordingly thrust out. The Glass being suddenly then clapped on the Part to be cupped, the inward Air in cooling condenses and contracts, and the Glass consequently adheres to the Flesh in Proportion to the Difference of the Pressures of the internal and external Air. The Protuberance of the Flesh becomes hereupon pretty considerable within the Glass, for two Reasons: One, from the Pressure of the external Air, which endeavours to thrust as much of that yielding Substance into the Glass as it can; and the other from the Expansion of the Air contained in the Fluid and Flesh, which causes it to rise undoubtedly

somewhat

somewhat higher therein than it would otherwise have done. The Glas being removed, the Part is immediately to be wounded by a Scarificator, which is a kind of Lancet with many Points, and then the Glas being a second Time heated, and applied thereon as before, Blood and Serofities from the same Cause, are forced from the wounded Vessels into the Glas; and when one has done its Office, and drawn sufficient, another is apply'd, till the intended Quantity be taken.

If instead of putting the Glas, when warmed, on the Flesh, it be put for Experiment's sake into a Plate of Water, the immediate Rise of the grosser Fluid into the Machine, will precisely shew to what Degree the Air therein was rarefied by the Flame; which pretty much depends upon the Dexterity of the Performer.

THE best Way of Cupping is by the exhausting Syringe, tho' the generality of Operators do not as yet chuse it. By Flame, the Air of a Cupping-glass cannot be well rarefied more than one half. By the Syringe, a very few Strokes will nearly exhaust it. The Difference of the Pressure in both Cases must be very considerable. If the Cupping-glass be two Inches over, it has been proved, *Page 172*, that the Pressure from without may in the first Case be perhaps twenty Pounds; in the second, it may sometimes exceed forty. The Blood-vessels in the Flesh may be able to sustain the first Pressure pretty well, but will certainly be closed

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under the latter, by which the Efflux of the issuing Fluids must needs be stopped. One Stroke on the Syringe, perhaps half a one, may produce the intended Effect in this Operation; and two or three may defeat it, for want of Judgment.

On the RISE of the SAP in PLANTS.

FRUITS also contain a great deal of Air, as may be demonstrated by placing a shrivelled Apple under an exhausted Receiver, which will thereupon immediately become fine and plump; and if the Fruit be over-mellow, the Skin will probably burst, and Part of the Pulp will be pushed forth in Froth.

THE Air contained in Fruits doth not a little contribute to their Growth, Perfection and Maturity, as will appear from considering the Manner in which the Progression of the vegetable Fluid is effected.

IF we take a small glass Bolt-head, heat the Bole of it at the Candle, and put the End of the Stem immediately into Water; that Fluid, on the cooling of the Machine, will be made visibly to rise up the Stem into the Head, on the Condensation of the Air before expanded by the Heat.

THIS Experiment will in some sort intimate to us the Progress and Rise of the vegetative

tative Sap, with the Cause of such Rise. The Head of the Machine represents the extreme and tender Parts of the Plant; the included dense Air, the Fluids lodged in those Extremities, and in general, those contained in the Cells of the whole Tree. The Heat apply'd, denotes that of the Sun in the Day-time, which not only immediately acts upon and attenuates the Viscidities of the Sap, but also serves to dilate and enlarge the Cavities of the Plant, which makes it enlarge itself and shoot. The Liquor rising in the Stem of the Glass, signifies that of the juices imbibed from the Earth by the Fibres of the Root; whence they pass by small Canals up the Body of the Tree, forwarded probably also by the Attraction of Cohesion within, as well as by the Pressure of the Atmosphere without, especially when the Fluids come to shrink and be again condensed in the more tender Parts of the Plant, by the succeeding Cold of the Night. Whence it happens, that Plants which towards Evening, being exhausted of their Juices by a too vigorous Perspiration in a hot and sultry Day, seem to languish and droop, but during the Night they recover, and again hold up their Heads without being watered at all.

WHAT greatly contributes also to the Motions of the vegetative Sap, is the great Mixture there doubtless is of Air in most of the grosser Fluids, which in the exhausted Receiver will visibly arise out of them like Steam, and get away; as may at any time be try'd on White-wine, or indeed any transparent Liquors that have

undergone any Degree of Fermentation. These are always replete with Air. Small-beer in particular is very much so; the Particles whereof in *Vacuo* evolve themselves and get away, notwithstanding the Viscidity of that Liquor, very notably. It may be observed also, that all Liquors by this kind of Operation become vapid and dead.

It may be farther remarked, that the Bubbles composing the Froth produced by these Experiments, always throw themselves into the Form of an hexangular Solid, which is the only Polygon whose Sides would every where meet, so as to leave no Vacuities between. The tubular Cells, made by the Bees in forming their Combs, are constantly of this Shape. Thro' Ducts of this kind, those Animals can pass with more Convenience and Freedom than if they had been either square or triangular; and had they been of any other Form, they would have been incompact, and less agreeable to the Sagacity and Contrivance of those curious and sedulous little Creatures.

WATER, even when cold, will visibly yield a good Quantity of Air, when the Atmosphere ceases to press on its Surface with all its Weight: But whenever the Spring of the incorporated Air shall be heightened by any Degree of Heat, it will appear to boil in the exhausted Receiver, and that so smartly, as sometimes to make it flash over the Cup.

IT may in making this Experiment be observed, that in this Ebullition of the hot Water, Part of the Heat will leave the Water, and be communicated to the Receiver : Whence it will appear, that Heat and Cold are not conveyed to Bodies by means of the Air. Besides, it is found on Experience, that Heat is propagated thro' a *Vacuum* with the same Ease, and in the same Manner, as thro' the Air: For if a Thermometer be suspended *in vacuo*, it will undergo precisely the same Variations with one hung near it in the open Air.

On the THERMOMETER.

WITHOUT entering upon the Nature of those primary Qualities of Bodies, Heat and Cold, Points very much controverted among the Learned, we for certain know, that 'tis the Property of Heat to dilate, and of Cold to contract, all natural Bodies whatever,

THAT they have this Effect upon the most rigid, as Metals, &c. appears from the common Experiment, of exactly taking the Length of a Bar of Iron cold, as between the two Cheeks of a Lathe; heat it a little and it will be so expanded in Length, and proportionably in Breadth, that it will evidently exceed the former Measure. And that these Accidents

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produce the same Effect on fluid Bodies, was before fully proved by the Experiments made on the hydrostatical Balance, mentioned Page 133. The sinking of the Water-poise deeper in all Liquors that are warm, in general shews them to be dilated, from their being in that Circumstance less buoyant than when condensed by Cold.

AND that Heat and Cold will act on the Air in like manner, will appear on filling a Phial one fourth Part with Water, suppose, or Mercury. Then screwing a Tube of some Length into the Neck, reaching nearly to the Bottom, as *AB*, *Fig. 2. Plate 9.* Blow a little Air thro' the Tube, which will lodge in the upper Part of the Phial; the Spring whereof will cause the grosser Fluid to rise, suppose to *C*. Immerse the Machine in cold Water, and the Air in the Phial will immediately contract shewn by the Descent of the Fluid from *C* perhaps to *D*. Take it again out of the Water, and lay a warm Hand on the Bottle, it will soon dilate, and push the Fluid up the Stem perchance to *E*.

If a Flask of Water, filled to half the Neck, be however immediately set on the Fire the Fluid will at the very first seem to sink therein, occasioned probably by the Expansion of the Glass being thin, and the Enlargement of its Capacity by the sudden Heat; but in very little Time it will rise again, and continue so to do, by the ordinary Action of the

Heat applied. But if a few Drops of Oil of Vitriol be put into such a Flask, the Parts of the Fluid will be constricted thereby, and as it were condensed, shewn by the sinking of the Fluid in the Neck of the Glass, as it really thence becomes more cold.

IT may here be observed by the by, that in thin Glasses Water may be boiled with great Ease, and without Damage to the Glass; whereas those that are thick on being heated most commonly crack and fly. In such the two Surfaces are necessarily at some Distance; and the outer Parts being dilated when set on the Fire, before the Heat can possibly penetrate to and affect the inner; so that two powerful Forces pulling different Ways are thereby constituted, which soon demolish the Glass or other brittle Body on which the Experiment shall be made: Whereas both the inner and outer Surface of such Vessels as are thin, lie so very near each other, that they, being heated and cooled much at the same Instant of Time, are therefore preserved.

OUR Organs of Sensation being in a State of constant Mutability, are very unfit to direct us in giving a positive Judgment of the Degrees of Heat or Cold in any Medium; for the Breath, which in the Summer seems cool to the Flesh, in Winter appears to it warm: And if we put a very warm Hand into Water moderately heated, and afterwards a cold Hand into the same, it will appear warm to this, but

cold to that. But in this Matter the Thermometer will most certainly assist us.

THE Machine mostly in Use for this Purpose, was invented by the *Florentine Academy del Cimento*, and is ordinarily a small thin glass Ball, having a long hollow narrow Stem. The Air being thence extruded by Heat, 'tis filled to a certain Height and Degree, according to the then Temper of the Air at that Time, with coloured Spirit of Wine, Quick-silver, or Linseed Oil; Fluids not subject to freeze. This done, the upper Part of the Tube is by a Lamp sealed up with some common Air unavoidably left in it, and by the Heat of the Lamp somewhat rarefied. This on Occasion will probably assist the Motion of the fluid Column, that is, hinder it from dividing in the Tube, when the Body of the Spirits comes to contract; upon which, otherwise a Part of it might be apt to hang by the Way, and would never regularly again move with the rest (the Tube being commonly small, and the Attraction of Cohesion between that and the Spirit therefore pretty strong) as often happens, it may be observ'd, in such Thermometers as from whose vacant Part the Air is pretty well extricated. In which Case there is no better Way of uniting the Spirits so divided, than by tying the Thermometer on a Board, and whirling it briskly about at the End of a String; the centrifugal Force of which will probably bring the disjoined Parts again to move and act together.

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THE Air included in the Stem will, on the dilating of the Spirits, indeed be a little condensed in these Machines; and therefore the more curious Artift usually makes an Allowance for it, by placing the Divisions of the Scale at different Distances. For by the upper Part of a Scale, equally divided, it might indeed be discovered, that the Heat of the Medium was increased; but it would be difficult from it to judge in what Degree.

THE original Air-thermometer had a Tube unsealed at Top, which tho' it might serve the present Occasion tolerably well, in ascertaining how much the Heat of the Hand or any Liquor into which it might be put, exceeded that of the Air; yet would it but uncertainly determine the Degree of Heat in the Air in general: Because, being exposed to the Atmosphere, it would also be affected by its Pressure, and of consequence rise sometimes too much, sometimes not enough; it is therefore at present not in Use.

THIS leads me however to describe a very useful Machine, contrived by Dr. HOOK, called from its Use, the *Marine Barometer*, consisting entirely of two Thermometers of equal Length, thirty Inches apiece perhaps, fixed in the same Frame side by side, as *Fig. 3. Plate 9.* One of which was exactly the Thermometer now in Use; the other differed from it only in having an Opening at *D*, whereby it was exposed at Foot to be acted on by the Gravity of the Air, as well as affected by its Temperature with

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with regard to Heat and Cold. Let us suppose these two Machines put together and filled, when as to each of these Circumstances the Air was in a middle Way; that is, the Weather about *Changeable*, the Air at *Temperate*, and let them be fitted up with proper Scales and Indices thus distinguished. If then the Pressure of the Air happened to be augmented, and its Temper not altered, the Consequence was, that the Liquor rose in the first, as suppose to *E*; but kept stationary in the second. This intimated the Air to be more ponderous, and consequently that *Fair Weather* might be then expected. Whereas had the second Thermometer risen by an Increase of Heat in a like Degree, as suppose to *e*, it would have indicated the Weather indeed to be warmer, but in the self-same Disposition with regard to Weight, as when the Instrument was first adjusted: And had they sunk in the same Degree, as to *G g*, just the contrary. These Alterations were easily to be observed and noted thereon, by help of a sliding Index fixed to a Wire, as *H*.

THE unavoidable Wasting of the Spirits, thus exposed to the Air at *D*, especially in hot Countries, was an Inconvenience that the late Mr. PATRICK removed, by substituting Quicksilver in the Room. His Method was this: *A*, Fig. 4. Plate 9. is a glass Vessel, capable of retaining a certain Quantity of Air. *B*, in the inverted Neck, is a small Cistern of Mercury, separated from the Glass with a porous and light kind of Wood, to keep it from shogging
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to and fro in Carriage, thro' which however the Spring of the Air included in *A* might at all times easily act, and by its Spring press on the Surface of the Mercury. These in his Machine ordinarily lie out of Sight; but the recurv'd Tube *EF*, communicating with *B*, and thro' which it may be easily filled with Mercury to the Level *BD*, where indeed the graduated Scale ought to begin, is produced to View, and is denoted in the Draught by the Letter *E*, Fig. 5. Plate 9. which is a Draught of the Instrument connected and put together. *H* is the Stem of a common Thermometer, appearing also to Sight; the Ball and upper Part whereof are bent backward and disposed of within. *G* and *K* are two fixed Scales unequally divided, both marked with the Distinctions and Terms of the Thermometer only. *I* and *L* are two sliding Scales, properly divided, marked like the Barometer exactly, with the Indications of the Weather, and the ordinary Divisions, viz. Inches and Decimal Parts, from twenty-eight to thirty-one; between which, as has been said, the Mercury in the common Barometer usually stands. These belong, as the fixed Scales do, to either Tube one.

Now if these Machines be put together, when the Air is in a middle State with regard both to Heat and Weight, the tinged Spirit in *H* will of itself naturally stand against *Temperate* on *K*. And by blowing or forcing Air into *A*, thro' the Body of the Mercury, by the Aperture at *E*, the Spring thereof may be so increased, as to throw the Mercury from the
Level

Level *BD*, *Fig. 4.* to the same Height on *I*, as the Spirit stands at on *K*. Things thus adjusted, should both Machines then rise or fall equally, 'twill only indicate a Change in the Temper of the Air as before: If unequally, it will signify, that an Alteration in Point of Weight has also happened therein, the Degree of which is by this Instrument to be readily discovered, by the following Method.

SLIDE the moveable Scale on the Side contrary to that on which you begin your Observation, for you may take either Side, till the Index thereof points out on its corresponding fixed Scale, the self-same Division as that against which the Section of the Fluid on the Part of the Instrument first observed happens then to stand: Upon which the Section of the Fluid on the one Side thus adjusted, will point out the Inch and decimal Part, marked on the Scale last moved, at which the Mercury in the common Barometer does then stand, together with an Intimation of the Weather. An Example may render this familiar. The Mercury, for Instance, in *E* stands, let us suppose against forty, on *G*. Let *L* then be moved till the Index thereof points likewise at forty on *K*; then will the Section of the Spirit in the Tube, on its moveable Scale *L*, indicate what Weather may be expected, with the Inches and decimal Parts, at which the Mercury then stands in the Toricellian Tube; and thus *vice versâ*.

As the Observation may at any time be taken on either Side of these combined Thermometers indifferently, they will always certainly agree as to the Weather: But with regard to the Temper of the Air, that will easily be known by Inspection, from the Spirit-side of the Instrument alone. This Machine is ordinarily about a Foot long, is very manageable, easily carried, and equally useful both by Land or Sea.

ACCORDING to the Improvement last mentioned, and contrary to the Usage of all other Barometers, the Mercury sinks in token of Fine Weather, and rises on the Approach of Foul: Because the Air's Pressure coming on it from above, the Tube *I* being open at Top, the Air included in the Vessel *A*, *Fig. 4. Plate 9.* beforemention'd, is either therein somewhat compressed on the Accession of new Matter, or dilated on the Abatement thereof: and this will be evidently shewn by the Rise or Fall of the Mercury in *E*, whenever it shall happen.

THE Scales of this Instrument are larger considerably, and the Divisions more distinct, than those of the common Barometer; since the Temper as well as the Weight of the Air are concern'd in its Performance. Dr. HALLEY had one of them with him in his *South-Sea Voyage*. He gives it a good Character, and says, he met with no Storm which was not evidently foreshewn by it.

On

On the HYGROMETER.

THIS Instrument shews the Disposition of the Air as to Moisture and Driness, and may be of good Use in judging when it may be proper to air a Room for the sake of the Books or Furniture, and may be very easily made several Ways.

FIRST, either by suspending a little Weight at the End of a well-twisted elastic String, suppose a Whip-cord; or else by fixing such a Weight in the middle of such a String, horizontally hung loosely over a couple of Tacks. The Moisture in the Air will generally contract the Cord, and raise the Weight; and in a dry Season it will naturally lengthen and lower it. The Weight in this Case may serve as an Index, and a few Marks made on a perpendicular Scale, will shew the Variations of the Air in these Particulars very sensibly. The Effects of which may in a little Time be discovered, by taking it, if portable, into a damp Vault, and afterwards setting it near a Fire.

THE twisted Beard of a wild Oat, with a small Index fixed to it, and a circular Scale, will make an excellent Hygrometer: For it will move by the Humidity of the Breath, while you look at it, unless particular Care be taken to prevent it.

CAT-GUT will also serve this Purpose very well, as may be observed by the coming forth of the *Man* or his *Lady*, depending on such a String, from the *Dutch Toy*, called the *Weather-bouse*, now well known here in *England*.

WHEN the Air is moist, the Particles of Water floating abundantly therein fix on all Bodies exposed thereto; they enter the Pores of such as are of loose and open Texture, and consequently dilate and swell them very much. Hence wooden Doors, Drawers, and the like, are generally found to stick in moist Weather. If Wood be not painted, it imbibes them as fast as they fall: If it be painted they settle on the Surface; and in damp Weather, the Wainscot stands on a Dew, and the Moisture sometimes gutters down in Drops. Glass, Marble, and other dense Bodies, of a smooth Surface, shew us this on every Occasion; but Cordage and the laxer Bodies admitting Humidity into their Vacuities with Ease, produce the Effect here proposed.

THAT there is a good Quantity of Water in the common Air at all Times, appears from the Halo, always seen in a clean Receiver while exhauſting, if the Candle be placed on the opposite Side. The watery Particles, dispersed every where more or less throughout the whole Body of the Atmosphere, according to the Difference of its Density, being intimately mixed therewith, and thereby sustained, are generally too minute

minute to be visible : But when the Air comes to be attenuated to a certain Degree, they begin to fall, and running precipitately together, become apparent and evident to Sense. The whole Glass, on such an Occasion, seems filled with a Mist, and the Candle view'd thro' it appears to be encircled with a coloured Ring ; but when the Air is wholly exhausted, these small Drops being no longer sustained, either fall to the Bottom, or are seen to settle on the Sides of the Glass in a kind of Dew.

THIS will also farther appear from the Dew that, in hot Weather especially, seems collected on the Outside of a Glass, or other smooth Vessel, upon the sudden pouring in of cold Water. By the great Degree of Cold, the watery Particles in the adjacent Air are at once condensed on the Surface, and become immediately visible thereon. The like also is observed to happen on the Windows in cold Weather, from a Condensation of the aqueous Particles interspersed in the Air within a Room : Which, if the Weather be inclined to Frost, will soon crust over the Glass with Ice ; but if it be open Weather, they ordinarily gutter down in Drops.

WARM Air, it may be observed, will always receive, imbibe and dissolve more Water than cold, in the same Manner that warm Water takes in more Salts than will a like Quantity cold. This appears to be so, from the Moisture of the Breath, wholly invisible in Summer-time, it being then easily received into

into and incorporated with the warm circum-ambient Air: But quite otherwise in Winter, when being condensed, as it proceeds from the Mouth, by the circumjacent Cold, it is with more Difficulty received therein; and therefore the Breath then remains visible, after Expiration from the Lungs, for some small Time.

ON the contrary, Water, according to Dr. HALE, will absorb good Quantities of Air: For if Water be well boil'd, and left to cool, it will be pretty well purged of its Air. Take then a glass Phial of it, stop and invert it, leaving a Portion of Air of the Bigness of a Hazle-nut suppose thereon; in twenty-four Hours time this will disappear, and the Phial seem fill'd with Water. Put in more Air, it will decrease in more Time, and at length be wholly incorporated with the Water, increasing the Bulk of it proportionably. But when the Water is well impregnated, and as it were saturated therewith, it will take in no more.

On the ORIGIN and PROGRESS of the
WINDS.

THE Air has been proved by many Experiments, to have in it a very fine and lively Spring; whence it endeavours, being either contracted or dilated, to return to its natural Degree of Density wherever it shall be. But as a farther Instance of this, we might exhaust any Vessel of Part of its Air; apply the Flame

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of a Candle to the Mouth, and on opening a Cock, the outward Air will forthwith rush in, and by the Motion of the Flame shew it does so. And again, if the Air be condensed in the Vessel, the included Air will push out, and puff the Flame outwards, till the Degree of its natural Density within, is justly equal to that of the circumjacent Air without.

FOR this Reason, the Air within a House, will always be of the same Weight and Force with that without; since it cannot but very freely communicate therewith by the Windows and Outlets. It will therefore equally press on all Bodies, and will evidently raise the barometrical Mercury as much within Doors as it would abroad. For should the Elasticity of the Air at any Time be increased by some accidental Heat within the Walls, or should the Air be so occasionally condensed by any extraordinary Degree of Cold without, a just Equilibrium will still be maintained between them, and the Barometer will be equally affected, notwithstanding those Alterations; the same Quantity of Matter being in either Case incumbent thereon.

THE due Consideration of this Endeavour of the Air to maintain an Equilibrium in all its Parts, will assist our Conceptions very much in tracing out the natural Cause of the Winds.

ALL Fluids, by the Laws of Hydrostaticks, endeavour to remain in a State of Rest, and by consequence immediately move, to make good the Defect, whenever this Rest is interrupted

rupted: The Atmosphere then is naturally inclined to maintain a peaceful Situation, in form of a hollow Sphere or Shell, all round the Earth; but various Accidents often conspire to disturb its Repose, and sometimes put it into very violent Motions.

Of these accidental Causes, none procure so constant and certain Alterations in fluid Bodies, as Heat and Cold. It has been already hinted, that a Gallon of Water may be so dilated by Heat, as to make near fourteen thousand times that Quantity of Steam; and it is evident to every Eye, that in boiling only, Water often enlarges its Dimensions very much. A Gallon of Water, over a brisk Fire, for Instance, will easily fill a two Gallon Vessel, and be made even to overflow, to which the Air incorporated with the Water may perhaps not a little contribute. Nor is there any Room to doubt, but was a Bladder of Air thrust into boiling Water, the Spring of it would be so heightened by the sudden Heat alone, as to burst the Bladder immediately.

Now as the Sun continually shines on a great Part of the Earth and its Atmosphere every Day, his Beams heat and exhale Vapours from the one, and rarefy and expand the other, according to the Degrees of Heat in the several Latitudes of the Earth received. Between the Tropicks his Rays are always vertical, striking perpendicularly on one Part or other of the torrid Zone continually, as he

arrives at the several Meridians successively all round the Globe ; of consequence therefore, the Air must be very much heated and expanded in those Places. In other Climates the Heat of the Sun is greater or less, according to their Situation and the Obliquity of their Aspect with regard to him ; and the Rarefaction of the Air in either Case, is in some sort proportionable to the Degree of Heat to which it is exposed.

FROM this Expansion of the Air, Motion is therein produced, the Parts adjacent being consequently thrust thereby out of their Places. This is every Day done, till the Sun has past the Meridian ; when his Heat abating, the Air, before heated and rarefied thereby, comes to be gradually condensed by the succeeding Cold ; and then, according to the Nature of Fluids, the denser and heavier croud again into the Vacuities made : And thus a Flux or Current of Air is produced, or what we call a Wind rais'd.

A DIGRESSION concerning FAULTY CHIMNEYS, &c.

TO make this familiar by a common Experiment, let us turn our Thoughts on the Wind-stove, which has a Plate to slip down before the Cavity of the Chimney, in order to contract the Channel, and confine the Stream of Air, by which the Fire is to be blown up. We know, that when this Plate is
down,

down, if the fire be well kindled, the Air will rush thro' the Bars like a Torrent, and make the Coals burn with great Vehemence; but if the Fire be low, the Stream that sets into the Chimney will be scarcely perceptible.

Now it is plain, that the Air both in the Room and Chimney, before any Fire was kindled, especially in serene Weather, might very probably be in a State of absolute Rest; and did not the Heat of the Fire attenuate the Air about it, it would so continue: But being expanded thereby and rarefied, it becomes specifically lighter than the Air adjacent, and consequently emerges, by hydrostatick Laws. This then mounting up the Chimney with the Smoke, the denser Air, by its greater Pressure, rises out of the Room continually, to supply the Vacancy. And thus, for the same Reason that blown Bladders rise in Water, a successive Flow of Air, or a Wind, by this kind of Stove is successively propagated.

By a Current of Air, or a Wind of this sort raised, the Machine called the Smoke-jack is turned. It consists of a circular Set of Vanes, disposed like the Sails of a good Wind-mill, obliquely to the Course of the Wind, in an Angle of about fifty-five Degrees, if made to do their utmost. These are fixed into a vertical Shaft or Spindle, communicating with a little other simple Wheel-work, coarse and fit for the intended Purpose; which, when the Fire is clear and hot, it drives about very briskly: Whence it appears, that

it is the Stream of the heated Air, and not that of the Smoke, which acts successively on the Vanes of this Machine, in much the same Manner as does a Stream of Water against the Blades of an Oar, or the Floats of a Water-wheel.

AN entertaining Experiment, to like Purpose, might be made by a Paper Lantern adorned with Figures, fixed to a very light circular Frame of triangular Tin Vanes, disposed in the Manner abovesaid, each of them four or five Inches long, and at the bigger End about one and a half broad. Under this Machine, the Center whereof is to be hung on a fine Pivot set upright, a lighted Candle may be put (not too near the Centre) the Flame whereof, we may observe, commonly ends in a Point (the adjacent Air being thereabout very much heated) on which account, the Flame also, endeavouring to rise with it, is protracted or drawn out, and becomes pointed in the Part where the Heat is most extreme. The Air thus rarefied, will rise steadily within the Paper, and giving successive Shocks or Strokes to the Vanes, will by Degrees make the Machine turn about pretty briskly, and always the same Way. The Experiment is represented, *Plate 9. Fig. 6.*

FROM the same Principle also is promoted the Circulation of warm Air, thrown into Rooms, after it hath been heated, undulating thro' hollow iron Plates, disposed generally in the Back and Sides of the Chimney. This is commonly

commonly let into the Room, or a Set of Rooms, through an Opening made somewhere above the Fire-place, and the Consumption thereby made, is constantly replaced by a Stream of Air, rising thro' a Pipe or Channel, which conducts it from abroad. In this Case the heated Air, first occupying the upper Part of the Room, descends by Degrees as low as the Opening of the Chimney, thro' which, having performed the Office intended, it ascends again along with the Smoke. And this Circulation of Air contributes very much to the Salubrity, as well as to the Pleasure of the Place.

It may here be observed, that all Obstacles to any Current of Air, when raised, put it to the Spring, and very much disturb its Progress, by throwing it often into Whirls and Eddies. And the Commotions therein produced by these fixed Objects, very often interrupt the peaceful Rising of the Smoke in Chimneys; an Inconvenience very rarely to be got over, unless the Funnels can be so raised, as that they may deliver their Smoke beyond the Reach of the disturb'd Air.

We frequently see a Chimney do its Office very well, except when the Wind is some one Way; that is, when the Air about the Chimney-top is by some Means or other ruffled or over-much agitated, *viz.* It is either thrown too fiercely on the Chimney, by the Length and Strength of the Gust, or perhaps by Depression not seldom down it; but more generally it is reflected from some Part

of the Roof or the adjacent Buildings, or else it is absolutely commanded by some Eminence that over-tops it. For Example : The Wave of Wind *A*, coming over the high Wall *B*, will pour down and prevent the regular rising of the Smoke from the Chimney at *C*, *Fig. 8. Plate 9.* whereas it might have been sheltered perhaps from this Inconvenience, had it been placed more advantageously something nearer the Object, as at *F*, or have escaped perhaps the Fury of the Blast in good measure, had it been removed to *G*. In the Choice of a Situation for a House, particular Regard therefore should be had to the Exposition of the Chimney-tops, and proper Care taken that they be neither commanded by any thing very much above them, or that the Roof and the adjacent Buildings be so disposed, that the Air about their Tops may probably not be disturb'd by Reflexion, especially when high Winds are abroad.

SOME Regard is also to be had to the Disposition and Make of the Chimney. As to the first ; it should, if possible, never be placed between Doors, into which brisk or boist'rous Winds may blow. This will interrupt the regular Rising of the Smoke, and often force it out of the Chimney. As to the second ; it ought to be so built, as to leave no undue Vacancies in the Funnel, or under the gathering Wings. These are often Lodgments for Air, that may frequently be disturbed, the irregular Motion of which must affect the Rise of the Smoke very much. 'Twill therefore be

be always right, not only to lead the Smoke as directly and as streight into the Shaft of the Funnel as possible, but also not to have that Funnel over large. For the same Reason, false Backs, and Holes made above the Fire-place in a Chimney, are little better than Receptacles for cool and agitated Air, and are seldom known to remedy the Inconvenience found, nor is it likely they should.

CONTRACTING the Funnel or Section of the Chimney occasionally, by a Sliding-plate, or Register. cross it, as is practised by Mr. PHILLIPS and others, who with Judgment undertake to remedy this Inconvenience, is a very good Way. When the Fire is just lighted, before the Air in the Chimney is much rarefied, and when there is a large and diffuse Column of Smoke to be carried off, the whole Area of the Funnel, commonly left from ten to twelve Inches square, is not too much for the intended Purpose. But as the Fire kindles, and gives more Heat, the Channel may on Occasion be contracted to very good Purpose; and so as to be something like, if not nearly equal to the confining the Draught of Air in the Wind-stove at Bottom.

A Contrivance of this Sort also, to shut the Funnel quite, might be added, of very great Use and Service whenever a Chimney should happen to be on Fire, that by wholly stopping the Draught of Air thro' it, it might be put out. By such a Device also, the over-great
Intense-

Intenseness of the Fire might easily be moderated, at any Time.

If a Chimney, not commanded by an Eminence, placed in an inconvenient Situation, or otherwise injudiciously disposed of, does not draw well, it can only proceed from the Want of a free Succession of Air, to ventilate and fan the Fire, and to re-place from time to time, the great Expence of that Fluid, necessarily mounting up the Chimney, when the Fewel is well kindled, on Account of the natural Rarefaction of it by Heat, already mentioned.

Now to remedy this in close Rooms, it will doubtless be of Service, to have an Opening left, with a Pipe or Channel from without, somewhere near the Fire-place, whereby regularly and in time to supply what Air may be wanted, to keep the Fire alive and brisk. And this, provided there be no In-draught of Air from Doors, Windows and other Openings in the Room, will certainly perform the intended Office to very good Purpose. But where large and freer Openings are, smaller Ducts, however judiciously dispos'd, cannot be expected to act: Since all Fluids naturally endeavour to pass, where the greatest Freedom, and the least Resistance is.

SUCH a Contrivance will not only contribute to the warming of the Room, but of preserving an equal Temper therein, by continuing the Briskness of the Fire, in the first Place, and in the Second, by not changing continually, as
 4 otherwise

otherwise must be done, the warm Air for cold. An Opening, suppose of two Inches square, might be very well placed, either behind the Back of the Stove-grate, where too it would generally be out of sight: Or the Air might easily be made to enter by a Crevice, a Quarter of an Inch broad, left round the Jambs and behind the Mantle-piece of the Chimney within, in which Places it would be neither inconvenient or unsightly; neither wou'd it be liable to be choaked up with Dirt. Was something of this kind admitted into Practice, Experience wou'd soon direct the Proportions, and point out the best manner of introducing an Improvement, which in our Climate, in small Rooms especially, seems to be greatly wanted.

AND here it may be remarked, that 'tis more prejudicial to Health, to sit near a Window or Door in a Room, where there are many Candles and a Fire, than in a Room without: For the Consumption of Air thereby occasioned, will always be very considerable, and this must necessarily be replaced by cold Air from without. Down the Chimney can enter none, the Stream of warm Air, always rising therein, absolutely forbids it: The Supply must therefore come in wherever other Openings shall be found. If these happen to be small, and the Consumption large, let those who sit near them beware: The smaller the Flood-gate, the smarter will be the Stream.

To prove this by Experiment, we need only hold a Candle to the Key-hole of the Door of the Room, where a good Fire is, and a constant Stream of Air will be found to enter plentifully thereat. Besides, it may easily be remembered, that in sharp Weather, when we have had a brisk Fire before us, our Heels have been often ready to freeze, merely from the successive Flux of cold and raw Air continually drawing toward the Fire to make good the Waste, or what goes up the Chimney. And for this Reason it is that publick Assemblies generally procure the Professors of Medicine many Patients. To which indeed might be added; the alternate Heats and Colds unavoidable in such Places, which are nearly equivalent to the very great and sudden Alterations of the Weather that generally give People unexpected Colds.

WAS a Man, even in a Sweat, to leap into a cold Bath, or jump from his warm Bed in the intensest Cold, even in a Frost, provided he do not continue over-long therein, and be in Health when he does this, we see by Experience that he gets no Harm. If he sits a little while against a Window, into which a successive Current of cool and fresh Air comes, even in Summer-time, his Pores are closed, and he gets a Fever. In the first Case, the Shock the Body endures is general, uniform, and therefore less fierce and affecting; in the other, a single Part, Neck or Ear perchance, is attacked, with the greater Violence probably, as it is done

by a successive Stream of crude and cold Air. And the Cannon of a Battery, pointed against a single Part of the Bastion, easier make a Breach, than were they directed to play singly upon the whole Face of the Rampart, and will admit the Enemy much sooner into the Town. But to return.

The CASE of the WINDS continued.

IN the Burning Zone, where the Heat of the Sun is most constant, as well as most extreme, the Course of the Winds is observed to be the most uniform and regular, whether we consider them as continual or periodical.

OF the first sort is the Easterly Wind, blowing constantly between the Tropics, in some Places as far as thirty Degrees on either Side of the Line, in others not so much: Of the second sort are the Land and Sea-breezes, which in those Climates regularly blow from Sea to Land in the Evening, and from Land to Sea in the Morning.

THE daily Revolution of the Earth being from West to East, upon her own Axis, the successive Rarefaction made in the Atmosphere by the Heat of the Sun, will be according to this apparent Course from East to West; and as the Air, thus rarefied, comes by his Departure to cool, and be again condensed, the Motion of it will follow the Rarefaction continued

tinued Westward, and thus is an Easterly Wind there perpetually propagated.

SOME indeed have ascribed the constant and perpetual East-wind, thus blowing near the Equator, to the diurnal Rotation of the Earth about its Axis from West to East, whence they conceived, that the Air on its Surface might seem to move the contrary Way, as being, from the *Vis Inertiæ* of Matter, in some sort left behind. But as here are also found Winds that blow from other Points of the Compass; and as the Air is known to press on the Earth by its Gravity like other Bodies, to rest upon it, and there being nothing to hinder it from freely moving and revolving with it, (which by the way must very soon happen) this cannot be the Cause of the Easterly Winds in those Parts.

DID the Sun never depart from the Equinox, the Wind would very probably there never vary from the East Point: But we find that as he draws towards the North, in the Course of his Declination, as far as twenty-three Degrees and near a half, the Rarefaction of the Air shifts Northward after him, and the Wind consequently follows, in the compound Direction from the North and the East, so long as the Sun continues North of the Line, that is, from *March* to *September*. And when his Declination is Southward, between *September* and *March*, for the same Reason the Flux of the Air is accordingly less or more Northerly; and in the Southern Hemisphere just the contrary happens. Which being

being agreeable to Fact, off at Sea, in all the vast *Ethiopic* and *Atlantick* Oceans, where there is nothing to interrupt, it makes the Physical Cause of Winds, here proposed, more than hypothetical.

THE Reason of this Variation is obvious. The equatorial Parts being hotter than any other, the Air in both the Northern and the Southern Hemispheres ought equally to tend that Way, and it generally does so when the Sun is in or near the Equinox. But as he declines toward the North Tropick, the Northern Current of the Air meeting in its Passage with the Eastern, produces a North-east Wind on that Side; as the Southern Current, joining with the same on the contrary Side of the Equator, there arises a South-east Wind.

THERE is no Doubt, but that if the whole Surface of the Globe was Sea, the before said Wind would blow with the same Regularity, in those Climates, quite round the Globe: But in regard great Continents do often interpose, and break the Continuity of the Oceans, Respect must also be had to what will follow from the Nature, Situation, and Disposition of their Soil, and other Accidents, which are capable of interrupting the steady Course of the Winds, and of making it in many Places variable and uncertain.

To account in particular for the Land and Sea-breezes, which alternately are observed to set

set on and off the Coasts in hot Countries, it will not be unnatural to suppose, That since the Water is found to imbibe and transmit many, or most of the Rays of Light falling thereon, and the Land to reflect them, that the Air, during the Heats of the Day, must be much more expanded and rarefied over the one, than is possible over the other: Besides, the Sea can yield none but unactive watry Particles, in Exhalations; whereas from the Earth, nitrous and other heterogeneous Particles may be exhaled, which meeting in the Atmosphere, and fermenting with each other, may greatly contribute to heighten the Spring, and conspire with the Heat to increase the Air's Elasticity, and cause it to rise more briskly above the Land. The denser Air from Sea then, setting in upon the Coast, will become a comfortable Sea-Breeze to the Inhabitants all Day; and the Air thus rais'd, and perhaps heaped above the Land, cooling by the Chill of the succeeding Night, may thence recover Density and Weight sufficient to thrust back the Air from Sea, and returning the Way it came may become a Breeze from Land.

AND hence one might expect, that the Progress of the Sun from East to West ought to produce rather a West than an East Wind. Since it should seem, that the Air being denser in the Western Hemisphere, from the longer Absence of the Sun, than in the Eastern, over which it had more lately past, might be apt to produce a contrary Effect to what is really done. And this would doubtless happen

was the Point of the greatest Rarefaction that, to which the Sun should at any Time be vertical. But as the greatest Heats are observed commonly to be rather two Hours after that Time, or some thirty Degrees to the East of that Point, the Proceſſion of the Sun toward the Weſt is in Favour of the Eaſtern Current of Air, two Ways: Firſt, as it meets with the Weſtern Current making toward it, and diminifhes its Efforts in the Courſe of the ordinary Rarefaction; and, ſecondly, by this Point's ſhifting of itſelf conſtantly Weſtward, whereby a new kind of Impetus is given to the Eaſtern Current, which being thus put in Motion, continues it regularly forward, and ſo gathers Power ſufficient to overcome the former, and drive it before, in its own Direction.

BESIDES the more general Cauſes of the Winds hitherto inſiſted on, *viz.* Heat and Cold, there may particular ones alſo be aſſigned. Such as, 1. The Approach or Elongation of the Moon in her Circuit round the Earth, and even her Attraction in the Meridian, may be reaſonably judged to raiſe a Swell of the Air, no leſs than of the Water, in the Tides. 2. Certain Exhalations, that riſe out of the Earth ſometimes and occasionally, in certain Places, in Earthquakes eſpecially, and from Volcano's. 3. The Fall of great Quantities of Rain, Hail, or Snow, cauſing thereby a ſudden Condensation or Contraction of the Air where that happens. 4. The ſudden melting of Snows, &c. on the higher Mountains, cauſing the great Con-

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denfation of Air near them suddenly to cease.
 5. Burning Sands, that often retain the solar Heat to a Degree incredible to those who have not felt it, causing thereby a more than ordinary Degree of Rarefaction in the Air adjacent. 6. The Opposition of high Mountains, that reflect the Winds, and alter the Line of their Direction, and such like. All which particular Causes may happen either to conspire with, and strengthen the general Causes before-cited; or may oppose in part, or lessen their Efforts, according to the Diversity of Time, Place, and Circumstance, in the Course of Things.

To these Particulars, and such as these, is owing the manifest Irregularity and Uncertainty of the Winds in Climates far distant from the Equator. Nor can it be Matter of Wonder, if in high Latitudes the Winds be found variable, since between the Tropicks (where it might be least expected, on account of the steady constant Heat of the Sun) in certain Places from Dispositions of one kind or other, Alterations are found in the general Easterly Winds themselves. For Example; in the Southern Part of the *Indian* Seas, and far from Shore, the Wind blows always from the East or thereabout, according to the ordinary Course thereof, in and about that Latitude: But 'tis observed, that in the North Part thereof, the Wind blows regularly from the East, as in other Places adjacent, but one half the Year, and then turns and blows directly from the West, for the other six Months; and these Variations, in particular

ticular Places, arising from particular Causes, are termed *Monsoons*: That is, when the Sun draws toward the North Tropic, the several Countries lying near the Coasts in the Torrid Zone, becoming hotter, reflect more Heat than the Seas beyond the Equator, which the Sun has left; the Winds therefore, instead of blowing thence to the Parts under the Equator, blow the contrary Way: And when the Sun leaves those Countries, and approaches the other Tropic, the Winds turn about, and blow from the opposite Point of the Compass. The Regularity of these Winds making them more than ordinarily useful in Navigation, they are from thence called the *Trade-Winds*.

NORTH of the Tropick of *Cancer*, it may be observed that the Moon has often a considerable Influence on the Winds, which in the Compass of fourteen Days, or half the Luration, ordinarily make an entire Revolution, and blow from all the Points of the Compass. At New, the Wind being at North, it passes on to the East in a few Days, then to the South, and so on to West, and returns to the North about the Full, in settled Weather. In unsettled Seasons, the Winds will often vary, and run a little backwards, apparently against the Course of the Sun, as from West to South-west, and so to South: However, they seldom veer quite round in this Manner, but stop at some of the intermediate Points.

WITH REGARD to the Variety of Winds, by the Curious observed to blow, at the same Time, in different Places of the Earth, this may proceed from several Causes, worthy of Attention. As first; It being plain, that the Winds always move in the Direction of a great Circle, or one that would, was it continued, divide the Globe into two equal Parts; and did the Wind proceed from two of the cardinal Points, that is, either from the North or South, it would then retain its Name over a great Part of the Globe; in that Case it would blow along the Meridian: But should the Wind proceed in any other Direction, it will seem very different in whatever distant Places it shall pass over unless under the Equator when it blows due East or West. Because every one acquainted with the Principles of Geography knows, that all Rhumbs, which give Denomination to the Winds, between the Equinoctial and the Poles, are not streight, but spiral Lines. For Instance; should a Wind set out from the Equator, in the Direction of an Angle of forty-five Degrees; in order to retain the same Name, South-west for Example, it ought to cross the Meridian of every Place, it shall pass over in the same Angle: But if it keeps right forward, that is impossible; because the Meridians are not parallel, but inclined Lines, all meeting in a Point in either Pole. Wherefore the Wind that is termed South-west in one Latitude, will always carry a different Name in another.

A second Cause of this Variation of Winds, observed in distinct and different Places, may be from the adjacent Air's being thrown into a kind of an Eddy, by the Passage of a furious Blast, over a particular Track of Land: As in Rivers, when the Stream is rapid in the Middle, the Side-water is always pushed obliquely towards the Banks.

A third Cause may be, when in two Places, at a great Distance from each other, there happens at the same time to rise great Quantities of Exhalations from the Earth, able not only to disturb, but drive the Air into Motion all round them. In such Case, there must necessarily rise two Winds, meeting each other in a contrary Direction to the very Point of their Congress.

THE fourth and last Cause usually assigned for this Phænomenon, is the Opposition of high Mountains, which reflect the Winds, and gather and turn them into a Course often very different from their first Direction. An Example of this we have in the Lake of *Geneva*, which spreads itself between two Ridges of Hills for twelve Leagues together. Here there are never known to blow any other than two Winds, that is, either up or down the Valley. The like happens, as the Seamen well know, off of *Genoa*, and several Places in the *Mediterranean*; when sailing with a steady Wind under Shore, they often meet with a Flood of

Air, or a Squall of Wind from the Openings of the Valleys, as they pass, directly crossing perhaps the main Current of the Wind at Sea.

A Gentleman who had used to convoy the *Greenland Trade* asserts, That about the Island of *Spitsberg*, is fixed a vast Ridge of Mountains of Ice, to which, from the Distance perhaps of fifteen Leagues, he has frequently, out of Curiosity, taking the Opportunity of a Wind blowing right upon them, endeavoured to sail towards; but when he was about half way, he found he always lost his Wind, and what did blow, was rather against him. This was occasioned, no doubt by the Reflection of the Wind thrown directly on and rebounding from those Eminencies,

ABOUT *November*, it may be observ'd, that we who live in a considerable Northern Latitude, are frequently visited with high and boisterous Winds. This may possibly proceed in part from the general Condensation of the Air in the North frigid Zone, where they begin about that Time wholly to lose Sight of the Sun. It may, in part, no doubt, also proceed from the Explosions of fermenting oily Matter, which, after a hot Summer, may be disposed to rise from the Earth in sundry Places when that Heat is abated, and occasion something like the Winds which are found to issue from the Mouth of Caverns, either when the Spring of the internal Air is heighten'd, as is said, or when the external is render'd less dense; much as a Blast
of

of strong Air will be pushed from Water boiling in the Eolipile. The Experiment to be made on which Machine is this: Take a globular Vessel of Copper, having a small Pipe fodered into its Side. Heat this Machine pretty well, and invert the Stem into Water: As the Eolipile cools, the heated Air will contract, and the Water will rise into the Cavity, and fill it in a Degree proportionate thereto; perhaps three quarters full. Then set it on a Chafing-dish of hot Coals upright; as it heats, the Steam will issue from the Pipe in so violent a Blast, that will blow a Torch or Brand, held in the Way, like the Bellows of a Forge. This Experiment is represented *Plate 9. Fig. 7.* Should the Eolipile be reversed when the Water boils, a smart Jet of Water would be thrown out of the Pipe by the Repellency and Force of the confined Steam: And was the Machine filled with Spirits instead of Water, it would in like Manner present you with a noble Jet of Fire.

SOMETHING like this Experiment may be observed to happen in burning green Wood. The Fluids contained in the Cavities and the Fibres thereof, being gradually dilated by the Heat of the Fire, push briskly forth: They often rend and burst the solid Wood to make their Way, and then issue in a Blast. The Action of the little Candle-bombs is also on the same Principle. These are pretty strong Bubbles of Glass, having a small Quantity of Water inclosed, which being stuck near the Wick of a lighted Candle, when the Water

comes to be much heated, will so expand as to burst the Glass with a surprizing Noise and Force.

FROM some Cause similar to this, we endeavour to account for the Origin of tempestuous Winds; such, for Instance, as are observed to blow, about once in ten Years, in the *West-Indies*, near the Islands called *Antilles*; viz. about *Cuba*, *Jamaica*, *Porto-Rico*, the *Caribbees*, *Lucayes*, *Sotovento*, and *Bermudas*: Hurricanes which blow, for the Time they last, with incredible Fury, lay Waste the Countries, and make strange Havock at Sea.

As Earthquakes are often felt there at the same Time, and Inundations often follow, 'tis more than probable, that great Quantities of nitrous and sulphurous Matter, fit for Explosion, being brought up to a fit Disposition by Fermentation (hereafter to be more fully explained under its proper Head) may get loose; and thus by the springing of Mines as it were of fermenting Matter, successively in several Parts of the Ocean thereabouts, the Devastation here described may be occasioned: And that not only with Regard to the Commotion of the Air and Waters, by driving away the Parts contiguous to these Explosions, in a very violent Manner; but also with regard to the great Havock made among the Shipping, and even the Fish, which are always found dead in those Parts, in great Quantities, after a Calamity of this Sort has happened:

happened : Animals, which were it not for some external Violence, proceeding from the very Bottom of the Deep, might be very well imagined to be shelter'd from any Inconvenience that might arise from the Agitation of the Winds or Waters above. Besides, these Hurricanes now and then present the Geographer with a new Island, and sometimes they sink one upon him, or take away a Part of the old. Which is also an Evidence, that the Cause of these very extraordinary Disturbances proceeds immediately from the Bowels of the Earth ; as indeed all outrageous Storms of Wind may, from a Parity of Reason, be very well presumed to do.

THE Motion of the Winds is generally in Waves, as appears by the Sound of Bells, which in small Intervals of Time are frequently observed either to increase or be diminished in the same Place very sensibly, just as the Gust directs it either to this Place or that. The Motions of the Waves of the Sea, evidently impelled thereby, often demonstrate this: Since they do not all break on the Shore in the same, but very different Places. It farther appears by the Effects often left by this kind of Storm ; where, in the Compass of a square League, we shall often find many Trees left standing, when many others, of equal Strength, and the same in Kind, have perhaps been over-turned. The Dancing of the Mercury in the Barometers of curious Make, on these Occasions, is another Evidence also of the unequal Compressions

sions of the Air, under this Circumstance: It likewise intimates, that Part of the upper Air is sometimes removed by the violent Gusts in a Storm, which on their Abatement soon returns.

WHEN two great Winds happen to be inclined to each other in an Angle of about fifteen or sixteen Degrees, 'tis certain they condense the Air at the Place of their Congress, and, according to the Rules of Percussion, make it flow almost a third Part faster than either of them singly did. Supposing then that each of these Winds were going with the Velocity of twenty-four Feet in a second, as *A* and *B*, *Fig. 9. Plate 9.* which is the usual Velocity of offensive Winds, against which it is troublesome to walk; the Wind compounded of these two, will proceed after their Confluence at *C*, with the Velocity of about thirty-two Feet in a Second, toward *D*. This appears from common Experience, as well as the Rules of Motion; and may be seen represented by the floating of a Paper, whenever there is a Fall at *London-Bridge*, or at any Sluice of Water.

WHERE Winds are of equal Strength, and directly opposite, they on Meeting destroy each other's Force, and there produce a Calm; but the Air will there be accumulated: Whence 'twill follow, that to preserve the Equilibrium the Air must flow back either Way, above the main Current, and occasion thereby two other

contrary

contrary, but more gentle Winds, to blow from this Place above.

Dr. DERHAM, in a curious and accurate Discourse on the Motion of Sound, takes occasion to say something of the Velocity of Winds; which from many Trials, he concludes, cannot possibly move, in the greatest Storms, above fifty or sixty Miles an Hour; and that an ordinary brisk Wind may proceed probably at the Rate of about fifteen Miles an Hour. The Course of some is however so gentle, as not to exceed a Mile an Hour.

If a boisterous Wind meets side-wise with another more weak, it carries away the Air nearest to it, and turns it round with a certain Velocity, and this we call a Whirl-wind. This ordinarily goes on with the stronger Wind, and carries with it whatever is not very heavy.

To something of this Kind is ascribed that extraordinary Meteor often seen at Sea, and sometimes at Land, very dangerous to Ships, and whatever happens to be in its Way, called the Water-spout. 'Tis mostly observed in hot dry Weather. Its first Appearance is in Form of a deep Cloud, whose upper Part is white, the lower black. From the lower Part hangs, or rather falls, what we properly call the Spout, resembling a conical Tube, biggest above. Under this Tube is always a great Boiling, and Flying-up of the Sea-water, as in a Jet. For some Yards above the Sur-

face

face of the Sea, the Water stands as a Column, from the Extremity whereof it spreads and goes off, as in a kind of Smoke. Frequently the Cone descends so low as to touch the Middle of this Column, and continues for some Time contiguous to it; though sometimes it only points to it, at some Distance, either downright or asslant.

IT is often scarce distinguishable, whether the Cone or Column appear first, tho' generally the Boiling or Flying-up of the Water has the Priority, and this immediately precedes its being form'd into a Column. Generally the Cone does not appear hollow, till towards the End, when the Sea-water is thrown violently up the Middle of it, as Smoke up a Chimney. Soon after, this Canal disappears, but the Boiling up of the Water continues some Time afterwards; and sometimes till the Spout forms itself, and appears anew, which it will do, on Occasions, several Times in a quarter of an Hour.

THE real Cause of so uncommon an Appearance, and so dangerous to approach, is as yet but little known, perhaps the Affair of Electricity excited may suggest hereafter a proper Solution: But Mr. DE LA PRYME, from a near Observation of two or three of these Spouts in *Yorkshire*, conjectures, that they are a Gyration, or whirling of Clouds, impelled by contrary Winds, meeting in a Point or Centre, and falling down in a great Tube, somewhat like ARCHI-

MEDES's spiral Screw, where the greatest Condensation and Gravitation is, by its working whirling Motion, absorbing and raising the Water with a prodigious Force ; thus destroying Ships at Sea, or rending off Arms of Trees, Thatch of Houses, &c. as it has sometimes, in passing over them, done at Land.

THE Dissolution of these Spouts may be ascribed to the Weight of the great Quantity of Water they generally have taken up, which impedes the Rapidity of their Motion, whereon their Force and even Existence depends. When they break, they let go their Contents, which overwhelms whatever is found underneath. To prevent the ill Consequences whereof, our Seamen, when near, endeavour to disturb and break them, by Noises, and the firing of great Guns, which puts the circumjacent Air into a Tremor and a Motion different to and opposite in some sort to that whereby they are impelled.

To conclude this Subject ; it may be remarked in general, That tho' it is difficult to assign a physical Reason as yet, for all the Varieties that happen in the System of the Winds, by reason of the Multiplicity of Accidents that happen in the natural Course and Circumstance of Things ; yet thus much do we know for certain, that in hot Climates, where Exhalations are more copious, Hurricanes, Tornadoes, and more violent Storms, are common and ordinary. In the temperate Zones, where the
Heats

Heats are less powerful, these Appearances are not so frequent or so furious. And in cold Countries, where, for want of Sun, the Air is alway pretty dense, the Winds blow more gently, and move with greater Steadiness than they are found to do in any other Parts of the Earth.

THE great Service the Winds are of to Mankind, in the Way of Mill-work and Machinery, will scarce bear the Mention, when we consider the vast Advantages the World derives from Trade and Navigation. By the Subserviency of the Winds, Ships of prodigious Burden are conveyed round the Globe with Speed, Certainty and Ease. The Earth is discovered by this means, the Nations are civilized, and the Redundancies of one Country made frequently to supply the Deficiencies of another. This again bears but a very small Proportion to the general Benefit these Tides of Air are of, in transporting to us those Particles of Humidity from the Ocean, which form the Clouds, and which water and fertilize the Earth. Were it not for these frequent Commotions in the Air, the Salubrity of it could not long continue: For all the noisome Steams and offensive Vapours, that rise over populous Places especially, would there hang, and stagnating, would render this common Magazine of subtile Bodies, a Mass of corrupt, putrid and infectious Matter.

*On the Natural Causes of THUNDER,
LIGHTNING, and METEORS.*

HAVING occasionally mentioned the Effects of fermenting Matter, in producing Earthquakes and extraordinary Storms of Wind, our next Enquiry may be, how far the same Cause may be concerned in the Production of Thunder and Lightning, and the other Meteors appearing in the Regions of the Air.

FROM Observation, the Atmosphere may very well be considered as a common Receptacle of all the Vapours exhaled from the Earth; and we see Effluvia from an infinite Number of other Bodies do ascend therein continually. All manner of Scents, for Instance, whether proceeding from grateful or fœtid Bodies, the Steam and Smoke of things burnt or melted, the Fogs and Vapours arising from damp and watery Places, the Emanations from nitrous and sulphureous Substances, those issuing from acid and alkaline Bodies, and, in a word, whatever may be called volatile, rises in the Air, and therein finds a Place according to their several Weights, as in a common Magazine.

SULPHUREOUS Steams rise from Volcano's, evidently in great Abundance; the Parts of which are so very fine, and have such a Repellency

Repellency in them, that they will continue to rise even in an exhausted Receiver, as may be try'd, by writing somewhat on a Paper with solid *Phosphorus*, which is a chymical Preparation from human Urine, usually kept in Water to prevent its Evaporation and Waste. This being put under a Receiver, will soon become visible, and rise into a kind of lambent Flame, emitting great Quantities of Steam, but will not scorch the Paper; and if you exhaust the Receiver, the same Appearance will continue with very little Variation.

VARENIUS, in his *Geography*, observes, that when the Spices in the Islands, where they grow, are ripe, the Seamen can perceive it, merely by the Smell, at the Distance of several Leagues. In the *Azore* Islands, such is the corrosive Quality of the Air, from the various Effluvia mix'd therewith, that the Iron, and even the Stones of the Buildings there molder very soon: Whereas in the Province of *Chili*, in *America*, the Quality of the Air is so very mild and friendly, that though one puts up a Sword into a Scabbard moist, there will never be found any Rust upon it. These different Effects undoubtedly proceed from the different Particles of Matter wherewith the Air in those Places happens to be impregnated.

THE Effluvia emitted from Bodies, may be reduced to two principal Classes, the Acid and the Alkaline, though some there be that appear

pear to be Neutral. The first generally proceed from Substances that affect the Taste in a piercing and pungent Manner; the Points of which are therefore presumed to be sharp, rugged, and much broken. The second often rise from the Substances formed of Particles appearing to the Tongue tart, rough and deterfive. These are supposed by some to differ from each other both in Nature and Form: Since, whenever two Fluids of these kinds are mixed together, a strange Conflict and Commotion immediately ensues.

THIS may possibly not only proceed from the Ineptitude of the Parts of their constituent Particles for uniting and coalescing; but also from the alternate Attraction and Repulsion of their Parts: And it is not improbable, but that there may be a Polarity in many other Parts of Matter, as well as in the Magnet and Iron, in which they are certain and incontestable. That there is such a Property in several fixed and chrystaliz'd Salts, is pretty apparent, by their always ranking and disposing themselves in one certain unalterable Manner, as often as they are reduced from a fluid to a fixed State.

AND to this ingenite Property of Attraction and Repulsion, it may with sufficient Probability be presum'd, that the intestine and fermentative Motion arising from the jumbling together and mixing of these kind of Bodies, is principally owing. The acid Particles, for Instance, in mixing

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ing Juice of Lemons and Salt of Wormwood, may be well conceived to attract some of the saline Particles stronger than before, and to repel others with as great a Force, according as their Poles in such Mixture chance to meet, and be obverted to each other: Hence arises a great Commotion between the acid and alkaline Corpuscles, and from their leaping and bounding alternately into and out of each other's Sphere of Activity, being themselves probably also of an elastic Nature, which must necessarily encourage an Ebullition, and often bring on an Effervescence, that may continue till all the Particles, both acid and alkaline, have met each other at their proper Poles of Attraction; which is no sooner done, but the Ebullition ceases, the Mixture subsides, and the jarring Particles then seem united in a friendly manner.

AND here it may be observed, that the Affair of Fermentation is, by the generality of the later Philosophers, allowed to be one of the obscurest Processes in Nature; and in a great Measure a Mystery, to which their Principles of Inequalities in the Attractions of Cohesion of Bodies do not fully reach: For Instance, in the Degree of Fermentation caused between Solids and Fluids, in order to procure their Dissolution, the Particles of the former are by them supposed to attract those of the latter with greater Force, than either those of the Fluid or of the Solid attract one another; whence the said Effect is thought to be produced. And with Regard to the Fermentation of Fluids with

Fluids

Fluids (or the Cause of the great Variety of beautiful Motions, which for a long Time together appear in Liquors, which either ferment of themselves, as Must or 'new Wine, or that become defecated by the Addition of Yeast or other fermentable Matter) they do so lamely account for the intestine Commotion, the Bounding and Resilition of the small and insensible Particles of those Bodies, arising without any mechanical apparent Cause, and producing such considerable Alterations therein, even tho' the Elasticity of the Air be admitted into the Process, that the abovementioned Hypothesis may be receiv'd, at least till Principles shall be discover'd, that will better correspond with the notable Activity of fermenting Matter, than a sluggish Inequality of Attractions and Cohesions seems to do.

It may however be objected, that this of fermenting with an Acid is sometimes but a fallacious Criterion of an Alkali: For Oil of Vitriol is the strongest and most concentrated Acid we know, and therefore whatever ferments with it should be of an alkaline Nature: Whereas 'tis certain that it will ferment with some Bodies that seem to be neutral, and even with some that are allowed to be acid. From a Mixture of simple Water, Quicksilver, Nitre, &c. only an Effervescence and Heat ensues; and these are, properly speaking, neither acid nor alkaline. Nor does the strong Acid beforenamed mix without some Commotion,

with Rhenish Wine, and many other confessedly acid Liquors.

IN answer to this, it may be offered, That tho' the Bodies mention'd may appear to be wholly of the neutral kind, it is not improbable but they may be heterogeneous, at least in some Degree: And tho' the Acid and the Alkali may so far predominate in some, as evidently to distinguish to which Class they belong; or they may be so happily mixed in others as to render that Matter difficult; yet when either of these come to be reinforced by the Addition of fresh Matter of either kind, and a Commotion and Contest happens to be renewed, it may prove no more than that the Discordancy of the Particles opposite in Nature is continued, which before were quiescent, as being then equally matched, and in the State of two equal and opposite Forces, mutually destroying each other.

VOLATILE Salts, such as are extracted from Hartshorn and the like, are of the alkaline kind. These are known easily to evaporate and be dissolved in the Air; not only by the strong Smell continually arising from them, but also the Abatement of their Quantity, if they be left any Time unstopped. Acids do the same thing, but in a less Degree; as may be inferred from the sour Smell hanging about, and rising from Vinegar, Spirit of Salt, and Things of the same Tribe: And these being distinguishable by the Smell, all Bodies that on the Mixture with them

them, shall ferment, may be presumed in general to be of the alkaline Kind.

PARTICLES of Matter, such as these, either rising of themselves, as being less dense than the Air, or exhaled from different Soils in the various Parts of the Earth, by the Heat of the Sun, however peaceful and innocent in their own Nature they may simply be, yet meeting with and being mix'd with other Particles of a different and a disagreeing Kind, may begin of themselves to ferment, and may so briskly operate on each other, as to produce very surprizing Effects; of which any one will be convinced, that has seen the Mixture of two Liquors of this Kind, from the sudden Ferment and Discordancy produced thereby; as of Spirit of *Nitre* or *Aqua Fortis*, and the Spirit of *Sal Ammoniac*, or Salt of *Tartar*. Even the Effluvia from these Bodies meeting in the Air, begin a Degree of Effervescence, and thence become sometimes visible. Hence it is reasonable to suspect, that our stinking Fogs, which have usually also some Degree of Heat in them, are thus produced by the Mixture of Vapours of different Kinds, rising from the Earth on certain Occasions.

THE Salubrity then or Unwholesomeness of the Air, in general, proceeds no doubt from the different Combinations of the heterogeneous Particles, that constantly make their Way into it: And healthful Seasons and Situations greatly depend on the Effluvia arising from the Soil

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of the neighbouring Places, or what happens to be waſted in the Winds. Many of which, tho' innocent and wholeſome in themſelves, yet being mixed, may become hurtful to Life; and, on the contrary, ſuch as are prejudicial thereto, may chance to be joined with Effluvia from Matters of a different kind, ſo as to have their Malignity mitigated, and may thereby become indifferent, and even healthful.

An Inſtance of the latter Sort may be produc'd from crude Mercury, and the Effluvia raiſed from Vitriol, common Salt, and Nitre, none of which are poiſonous alone; but when they come to be mixed in the Air, being ſublimated by Fire, become the moſt deadly of all Poiſons, namely the *Corroſive Sublimate*. And from Chemistry we farther learn, that this very pernicious Poiſon, being raiſed again in like manner, that is, re-ſublimed with other Quickſilver, loſes by Degrees its noxious Quality, and becomes the good and wholeſome Medicine called *Mercurius dulcis*, or *Calomel*.

It may here be obſerved, that raiſing any of theſe Subſtances into the Air, ſimply and unmixed, makes not the leaſt Alteration in them; ſince *Sulphur*, *Camphire*, *Sal Ammoniac*, *Mercury*, diſtilled Waters, and even *Tin*, when ſublimed by Fire alone, provided the Fumes be intercepted by Glaſs, or ſome other ſolid Matter properly placed, to keep them from a total Evaporation, will be converted again into Bodies fully

fully possessed of all the Properties they originally had before the Operation, but more purified.

THE Atmosphere then being the common Receptacle of all subtle Matters less dense than itself, it cannot be disputed, but that Particles of very different kinds are constantly rising therein in great Abundance. And as acid and alkaline Matters, on meeting, always naturally and evidently begin on each other some Degree of Fermentation and Effervescence, we cannot be long at a Loss for a Cause of the ordinary, but sufficiently dreadful Phenomena of Thunder and Lightning. It is therefore more than probable, that the Parts of the Atmosphere next the Earth may abound with spirituous Particles, perhaps of the nitrous kind; and that at certain Times, and on certain Occasions, other Particles may be exhaled from the Earth, of a sulphurous, unctuous, or combustible Nature, which will act vigorously on each other, and take Fire, when they are brought up to a certain Degree of Heat by Fermentation.

THERE may also be a thin kind of Vapour, Damps or Steams arising from mineral and subterraneous Bodies, which being let loose into the Air, and meeting with the Nitre or other Salts thereof, though neither of these may have any sensible Degree of Heat in them separately, will ferment and act so briskly on each other, as to produce an actual Flame.

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THIS is what has often happened in Mines, and especially if those Vapours chance to be kindled, as they sometimes are, by the Lights the Workmen use; though very often they fulminate of themselves, and then the whole Train of Matter, mixed with the contiguous Air, will immediately take Fire, and, like a Train of Gunpowder, run from one End of the Vapour to the other. And this is done with that Swiftness and Violence, that it frequently destroys the Miners, blows up their Works, and produces as fatal Effects as if a Quantity of Gunpowder had been fired in the Mine.

SOMETHING of this kind may be obtained from Experiment, by putting some Iron Filings into Spirit of Vitriol in a Phial; stop them up a short Space together, and a Fume will rise from this Mixture, that will fulminate when apply'd to the Flame of a Candle. One Part whereof being kindled, 'twill immediately be communicated to the whole, the Fume being dense, much as all the Parts of a Quantity of pounded Resin, thrown from the Hand into the Air, near the Flame of a Candle, seems to blaze all at once; which is the Manner in which, at the Theatres, Artificial Lightning is made.

No sooner shall the Mixture just above proposed be made, but 'twill fall immediately into Motion, and quickly become sensibly warm to the Hand; and no one that has seen the sudden
Ferment,

Ferment, the vigorous Ebullition and Effervescence frequently produced between Bodies of this discordant, jarring Nature, but will readily allow, they can only be brought about by the reciprocal and vigorous Action of their Particles upon each other.

THERE are indeed Experiments, wherein such Mixtures are found to bring on a Degree of intense Cold, sensible to the Hand as well as shewn by the Thermometer; and by which our artificial Congelations are effected. As the former, by the Activity and Repellency of their Particles, heat and rarefy the compound Fluid; so these, from a Prevalence of Attraction, perhaps, and from an Aptitude of their Parts to unite, fall into and fill the Interstices of each other, when the Commotion ceases, become thereby condensed: And 'tis observable, that Bodies are generally cold in Proportion to their Density. Hence it is that Water is always colder than Air, and Mercury than Water; Plaister than Boards, and Marble than Plaister.

It has been said, that a convenient Mixture of Sulphur and Filings of Steel, with a little Water stirred briskly together, will not only produce a great Effervescence, but will sometimes break out into an actual Flame. From something of a like Cause probably proceeds the extraordinary Heat found in the *Bath Waters*, and other hot Springs; wherein two Waters, of themselves actually cold, flowing through Veins of chalybate and sulphurous Matter,

Matter, within the Earth, on mixing together may produce this Effect.

IN the same Manner also we account for the Conflagrations of *Ætna* in *Sicily*, *Vesuvius* in *Naples*, and all other Volcano's or burning Mountains. These were kindled at first, no doubt, by the Discordancy of a fit Mixture of Sulphur and Particles of Iron Matter in the Bowels of the Earth, which, when the Ferment was become sufficiently strong, broke out into a Flame, that has burnt for many Ages, and which will continue to burn so long as Matter shall be found for a Supply in those Places. The great and sudden Eruptions they sometimes make, are probably occasioned by the Influx and Accession of new Matter, that, in the Course of the Conflagration, gets vent in the Chasm. And from a like Cause, as has been already hinted, the Earthquakes, usual in these Places, and sufficiently dangerous, are justly thought to proceed.

THE Effects of Thunder and Lightning are so like those of fired Gunpowder, that they be reasonably judged to proceed from the same, or nearly a like Cause. The principal Ingredients of that mischievous Composition are *Nitre*, *Sulphur*, and *Charcoal* pounded together; which last being by Nature light and apt to take Fire, is added only to keep the Parts of the other Ingredients at a due Distance, that they may be suddenly kindled, and to increase the Blast. Whenever then proportionable Quantities of nitrous
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and sulphurous Vapour chance to be admitted into the Air, and those by any Accident there take Fire, their Exploſion muſt be attended with both the Flame and Noiſe obſerv'd in fired Gunpowder; which being once enkindled, the Train may be well expected to run from Place to Place, as the Vapour leads, and with the like Effects. And it may be obſerved, that for this Reaſon, the Flaſhes of Lightning ſeem one while to dart right forward, at other Times to vibrate hither and thither, according to the Courſe of the inflammable Matter, and as it ſucceſſively takes Fire.

LIGHTNING is more or leſs dangerous, according as the enkindled Vapours happen to be more or leſs denſe. If from its Rarity it aſcends pretty high in Air, it there flaſhes without doing any great Harm: If it be denſe, and hangs about the Earth, it whizzes about our Ears, ſweeps along the Ground, deſtroys, or at leaſt drives away the Air wherever the Torrent comes, kills Men and Cattle, and does a deal of Miſchief.

THAT kind of Lightning which makes the greateſt Havock, is obſerved moſt frequently to take Fire in the upper Regions of the Air, whence it uſually comes ſlanting downwards towards the Earth, and often directs its Force, being perhaps thereby drawn in a manner to a focal Point, againſt a Tree or Tower, or ſome eminent Object, on which it often produces ſurpriſing Effects, by piercing and dividing the moſt intimate Parts of hard Bodies, and writhing,

writhing, rending, and contorting those that are tough in a strange and very violent manner. These more noxious Blasts probably proceed from the gradual Rise of Clouds of Matter, proper for Fulmination, from the Earth, in these stormy Seasons; the upper Parts of which meeting with fit Matter, either found in, or produced by the Air, come to be first fermented, and then taking Fire, pursue the Track of the rising Vapour to the very End, where perhaps a great Part of the Force of the whole Blast may be made to concenter, something like the Rays of Light refracted into the focal Point of a Burning-glass, with such a resistless and impetuous Force, as may dissolve one hard Body, calcine another, perforate a third, entirely change the constitutional Parts of a fourth, by giving them quite another Direction, and so on. At the same time, it has been frequently observed, that this impetuous Flame which menaces Mortals thus magisterially, and rives and reduces to Atoms the hardest Things, will often pervade Bodies of a looser Texture without Harm: For it has sometimes not singed the Purse wherein it has melted the Money; and at other times dissolved the Sword, without damaging the Scabbard.

OUR late Experiments in pursuit of Electricity, have abundantly exhibited to View, the Plenty of ætherial Fire, wherewith the Atmosphere, as a grand Magazine, is every where stored. And it may well be expected, that this subtle Matter, evidently of the Nature of
Lightning,

Lightning, if it does not primarily begin, yet will it be allowed readily to promote all Explosions of this kind.

WHAT we call Thunder, is produced merely by the sudden and violent Motion of the Air contiguous to the Flash, in endeavouring immediately to thrust itself into the Vacuity thereby made. This frequently shakes the whole nervous System of Animals, and always affects the Ear in the same Manner as does the Explosion of Fire-arms, or the Bursting of a Bladder, when the Air is drawn from under it by the Air-pump: This Experiment is mentioned, Page 174. Now it is impossible that the rending of a Bladder, which can tear only like a Piece of brown Paper, should produce any such Effect. But as the whole Body of the adjacent Air moves on that Occasion, to make good and fill the Vacuity made, this is what affects the Organ of the Ear, in the manner spoken of: And 'tis thence reasonable to conclude, that all the Vacuities made therein, whether produced by actual Flame, or otherwise, will always be attended with the like Effect.

FROM the continued Length of a Clap of Thunder, and from its various Degrees of Loudness, it may be concluded, that the Lightning really is a Track of running Fire; which though it may seem to be instantaneous, and to fill as it were the Hemisphere with Flame at the same Time; yet is it propagated successively, and from different Distances, as will appear

appear by the gradual coming on of the Clap thereby produced, to the Ear, and with a different Degree of Force.

How far off, or how near we are to the Danger attending this War of Elements, may in general be estimated by the Length of the Interval between our Seeing the Flash, and Hearing the Clap of Thunder. For though they are instantaneous, and both produced in the same Moment, yet Light moving by many Degrees faster than Sound, they come to our Senses, and affect our Nerves successively. The Motion of Light is discovered, by the Eclipses of *Jupiter's* Satellites, to move progressively at the Rate of about ten Millions of Miles in a Minute; so that we may very well take the Time of our seeing the Flash, coming from a Cloud often within less than a Mile of the Earth, for the very Instant of the Explosion: Whereas Sound, by good Experiments, is found to move but at about the Rate of one thousand, one hundred and fifty Feet in a Second. We may therefore, in round Numbers, reckon that so many Seconds as pass between the Lightning and Thunder, so many thousand Feet at least is the Mischief from us. And if these happen to be considerably great, and immediately succeed one another, they may rightly be judged to be very near at hand.

CHEMISTRY will furnish us with several Subjects, peaceable and quiet in themselves, but which will, the Moment they are mixed, start into

into an actual Flame. Of this sort are most of our distill'd Oils, those from vegetables especially, which are full of Salts, as appears by their sinking in Water; and most of the acid Liquors immediately fermenting with them, shew them also to be of the alkaline kind. If, for Example, we take a few Drops of Oil of Cloves, or Oil of *Guaiacum*, and pour a small Quantity of double *Aqua fortis*, or rather *Glauber's* compound Spirit of *Nitre*, on them, distilled from *Salt-Petre* and Oil of *Vitriol*, a very strong Ferment, accompanied with Flame, and if the said Spirit of *Nitre* be new, strong, and very pure, an Explosion will also follow. The Manner of which is represented *Fig. II. Plate 9.* To this may be added a small Quantity of Gunpowder, to be fired on the Effervescence of the other Ingredients, for no other Purpose than merely to augment the Inflammation.

It must not be expected, however, that from hence we should precisely determine the particular Species of Effluvia which compose the Mixture, that floating in the Air will ferment, kindle, and flashing like Gunpowder, occasion those Explosions and rapid Streams of Fire ordinarily called Thunder and Lightning. But that there is in Lightning, very probably, a Mixture of sulphurous Vapour, appears in great measure from the sulphurous Smell that commonly attends it. Sultry Heats, a heavy-loaded kind of Air, are usually the Forerunners of it. And the frequent Consternation of the Inhabitants of the Kingdom of *Naples*, where
Sulphur

Sulphur greatly abounds, on Account of Earthquakes, and this kind of Storm, both proceeding, as has been said, from nearly a like Cause, is an Intimation that Sulphur may very reasonably be admitted as one principal Ingredient therein.

AND that Lightning has in it a nitrous Vapour, or some other Salt of equal Virtue and Strength, is at least probable for several Reasons. One is, from the very great Advantage Rain and melted Snow, both which cannot but be well impregnated with the aerial Salts, have over other Water in the Way of Vegetation; to the former of which it seems so very material and necessary, that even the Weeds at the Bottom of Rivers are not observed to grow or shoot but in wet and showery Weather.

A second Reason may be deduced from the Difference of Colour observable between the venal Blood, which is blackish, and the arterial Blood, which is of a florid red. The last of these having newly circulated thro' the Lungs, and therein been mixed with, or at least cool'd and refreshed by the Air inspired, immediately becomes of a brighter Colour: Whereas the former, having received that Benefit but sometime before, seems to want that Advantage. Besides, the Blood issuing from the Veins is observed to become immediately florid, if a Piece of Saltpetre or some other Salt be put into the Bason, and the *Serum* or wheyish Part of it grows thereupon pellucid as Water. It may also

be farther observed, that however black the Blood may appear when the Vein is first opened, it soon grows more florid when it has stood a little in the Air.

AND thirdly, Saltpetre, or Nitre itself, generates Air in Plenty, as is evident by putting a Piece of it into a strong bright Ash-lye, which is usually so replete with other Salts that have so well filled up the Interstices of that Fluid as to have dispossessed it entirely of the Air; and from which alone *in Vacuo* therefore no Air will seem to rise; but from the Saltpetre at Bottom it may be observ'd then to issue very fast.

TILL the Air can be perfectly analized, 'twill be impossible to speak of its constituent Parts with the desired Certainty. And tho' it must be allowed that there are other Methods known of rendering Water vegetative, and of making the Blood florid, without the Help of Nitre; and tho' Dr. HALEs has put the Admission of Air into the Composition of almost every Thing as well as Nitre, past all Doubt; yet as there is nothing, we are informed of, capable of so sudden or so violent a Degree of Explosion as Nitre is; therefore the Philosophers chuse to offer that as a necessary and a probable Ingredient of the Phænomenon under Consideration.

SOME Coruscations or Flashings there are, which in serene Weather seem to glide from the Zenith, or upper Region, often towards the Horizon, without Symptoms of Noise or Violence,

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called flying Dragons or shooting Stars. These doubtless proceed from much the same Cause as the Lightning. Certain more sluggish Vapours exhaled from the Earth by the Heat of the Sun to such a Part of the Atmosphere as may afford them Matter fit for Ignition, being lighted as above at one End, and being of no great Breadth, the Flame runs steadily forward; just as a small and even Train of Gunpowder fired in the Air would appear to do.

THERE are other Kinds of Flashings sometimes seen in the Air, such is the *Aurora Borealis*; those Glades or Gleams of Light that have of a long time appeared Northward, and of late have frequently been observed in our own and still more southern Climates in serene Weather. These seem to bear some Affinity to the Lights just mentioned, and are probably produced from something of a like Cause.

WE know from Experiment that there are some Steams, such as inflammable sulphurous ones, which are capable of so great a Degree of Expansion, that they become specifically lighter than the Air they float in, even tho' rendered as rare as well it can be by Art (which, as was before observed, *Page 156*, is within one sixtieth Part of Perfection) For they will rise to the Top of an exhausted Receiver, and there adhere: Those of Gunpowder fired in *Vacuo* in particular will do this, and so will all such whose Particles have so great a natural Repellency in them, as to produce this Effect. And as by

the urinous Vapour, by the Phosphorus emitted, and mentioned, *Page 272*, is visibly done.

STEAMS or Exhalations therefore of this kind rising from the Earth out of Mines, Volcano's, &c. must necessarily be buoy'd up towards the Top of the Atmosphere (and that they are so, appears from their being visible in many Countries at the same Time : As was that famous one in *March 1716*, seen from the West of *England* to the East of *Poland*, over thirty Degrees of Longitude, and perhaps a great way farther) or that rise at least till they come into a Region where the Air is expanded as much as by the Air-pump can be done.

THESE Effluvia, according to the ingenious Mr. ROWNING, in his late Treatise on these Subjects, being thus generally raised to the Top of the Atmosphere, or near it, and floating there, will, as he supposes, be necessarily carried towards the polar Parts of the Earth. First, because the superior Current of the Air to a great Distance from the Equator, is, from the general Rarefaction by the Sun's Heat there made, constantly presumed to be that Way. And, Secondly, because from Experience we know, that whatever swims upon a Fluid which revolves upon an Axis, as the Atmosphere does, is by such Rotation carried toward that Axis. This probably may be the Case of these Effluvia, and therefore their Appearance is generally made near the polar Parts of the Earth ; when, being there collected, of an inflammable Nature in themselves, and meeting with other heterogeneous

Particles in those Regions, proper to produce such an Effect, they appear to emit Streams of Light, become successively conspicuous, seem to glimmer as they rise, and being very thin, are soon consumed and disappear, without making the least Noise, or doing any Mischief whatever.

As to the Objection commonly made to this and the like Hypotheses; Where were these supposed Effluvia when the *Lumen Boreale* was scarce ever, or according to History very rarely seen? It may be answered; First, that the Vapours of which Clouds are formed, never rise so high as the Region in which the Matter of this Light is from late Observations known to float: It is therefore not inconsistent with the Theory, if it be often intercepted from our Sight by the Interposition of Clouds below. Secondly, that the Rise of the Emanations spoken of, is purely accidental, and may depend on several concurrent Circumstances. It may reasonably be presumed, for Instance, that the Air, or Earth, or both, may be sometimes, tho' but seldom, and perhaps with very great Intervals, disposed to produce this Phenomenon; just as some Seasons and some Years are found to be incommoded with Thunder and Lightning; whereas in others little or nothing of that Sort appears.

As to the *Ignes fatui*, the Will-o'-Whisps and such Appearances as are seen by Night near the Earth, about Pools and watery Places they are of the same Class and Tribe: But being a more heavy kind of Vapour, and one that hangs

hangs about those Places, they burn more slowly, and like a lambent Flame, having wavered a while to and fro, they commonly die much about the Place where they had their Birth.

FLAME is a most elastic Fluid, and 'tis generated by the vigorous Activity of the minuter Parts of Matter one upon another. Thus Flame may be produced by the violent Rubbing of two Boards together; nor is Flame any other than an enkindled Smoke: For Bodies do not flame without emitting a copious Fume; and the Parts nearest the fuming Body, or the hottest, are what form the Flame. Smoke passing thro' Flame, cannot but grow red-hot; and red-hot Smoke can have no other Appearance but that of Flame.

ALL inflammable Bodies, as Oil, Tallow, Wax, Wood, Pit-coal, Pitch, Sulphur, Gums, and the like, by flaming, waste and vanish into burning Smoke. If the Flame be extinguished, they smell very strongly, and the Smoke is then very thick and visible: Whereas by the Flame more of the combustible, unctuous Parts are consumed and lost, and then the Smoke is not so copious, nor the Smell so strong.

IN distilling hot and ardent Liquors, if the Head of the Still be removed, the Vapour will all take Fire at the Flame of a Candle; the Fume will in that Case be all turned into Flame, and from the Suddenness of it 'twill acquire a mischievous Force, like that of fired Gunpowder; the Spring whereof we experimentally

tally fee is able to overcome the Tenacity and Cohesion of any Bodies : 'Twill lift and rend even Rocks and Bastions, provided it be thoroughly confin'd, and the Abutments good. This is the Case of Mines that are sprung with any Success, and of the Bullets and Bombs projected from the Chambers of Ordnance and the Barrels of Fire-arms : If any of these get Vent, and an over-large Touch-hole will give it, the Projectile certainly miscarries.

Now there is no Flame to be raised from any Substances, besides that of Gun-powder, that will bear to be compress'd without being extinguished ; but the Intensity of this is such, that being once raised, it cannot be put out. In all Explosions made thereby, it must be allowed, that a few Corns of it can only take Fire at first ; and that the Flame spreads and increases, till the Spring thereof becomes not only an Equilibrium to, but also often greatly overpowers and surprizingly projects the Weight to be removed. Hence a Quantity of Powder, confin'd in the Barrel of a Piece, will lift an infinitely greater Weight than will a like Quantity fired beneath it in the open Air ; and for the same Reason, a Charge of Powder, with a Wad upon it, will do greater Execution than an equal Quantity thrown loosely into the Piece, and so fired.

THAT all the Powder is seldom burnt before the Explosion made, and therefore the Spring of an ordinary Charge of Powder is never brought to the highest Pitch it might be, appears

pears from the Trail of Powder observed commonly to lie scattered on the Snow near the Muzzle of the Piece in Fowling: And if a Charge of Powder be fired pretty near against a Mark smeared over with Wax or Tallow, 'tis odds but many Grains of unburnt Powder will be found sticking thereon.

THE rifled-barrel'd Pistol therefore, that is, such as by the Narrowness of its Bore keeps the Powder longer confined before the Exploſion of the Ball, is found to do greater Execution than one of equal Dimensions without ſuch an Advantage. And in general it may be obſerved, that thoſe Fuſils which have their Touch-holes ſo diſpoſed, as moſt readily to communicate the Flame to the greateſt Part of the Charge, and to light it more equally before the going off of the Piece, will always kill at fartheſt Diſtance. And for the ſame Reaſon it is, that the longeſt Guns with equal Charges of Powder, are alſo generally found to have this Effect.

GUNPOWDER fired in *Vacuo*, and when the Reſiſtance of the Air is removed, makes no Exploſion at all; but goes off Corn by Corn, as if they were ſingly lighted. This Experiment is repreſented *Plate 9. Fig. 10.* *A* is a Receiver, with the Reſervatory for Gunpowder at Top. *B* is a red-hot Iron put in before Exhaustion at Bottom. If when it is exhausted, a ſmall Quantity of Powder be let down from *A* by a Contrivance paſſing thro' a Collar of Leathers, which will allow of the ſliding of a Wire without admitting

any Air, the forementioned Experiment may easily be made. But if it be several times repeated, the Exhaustion ought to be continued to prevent Mischief; because the firing of the Powder generates Air, as may be observed from the sinking of the Mercury during the Operation in the Gage-tube.

On the Rise of VAPOURS, their Formation into a CLOUD, and their Resolution into RAIN, &c.

IT cannot be denied, but that the Air is at all times more or less full of humid Particles, as appears by their falling in an exhausting Receiver, producing the Halo, and the other Experiments of the same Sort mentioned Page 239, and the following. It is no less certain, that more Moisture will be taken up and imbibed by Air in Motion, than Air at Rest; as is evident from the Drying of Linen and other things that are wet, much sooner when there is a Gale of Wind, than in calm Weather. Besides, Dr. HALLEY's Experiments related in the *Philosophical Transactions*, put this Matter past all Doubt.

THIS Gentleman, in order to account for the Circulation of Vapours, caused an Experiment to be accurately made by the Operator to the *Royal Society* at *Gresham College*, whereby the Quantity of Water raised and carried off in Vapour from the Surface of stagnant Water, in a Place as free from Sun and Wind

as might be, was determined to be exactly eight Inches deep or perpendicular in a Year. This fell very much short of the Quantity of Rain found by the *French* Academicks to fall in a Year at *Paris*, viz. full nineteen Inches perpendicular: And shorter still of the Observations of Mr. TOWNLEY; who, at the Foot of the *Lancashire* Hills, lying in the Neighbourhood of the *Irish* Sea, found there fell in a Year above forty Inches of Water perpendicular. So remarkable a Difference makes it evident, that the Sun and Winds are the principal Causes of the Evaporation of Fluids; the one to raise the Vapour, and the other to carry it off and disperse it.

THE Doctor, in the same Course of Observations, takes Notice of the Vapour, seeming at sometimes to adhere or hang about the Surface of the Fluids whence they rise, cloathing them as it were with a Fleece of vapourish Air; at which Times the Evaporation appeared to be very little, by the small Quantity of Water then lost in twenty-four Hours: And as this was observed to happen commonly when there was very little Wind stirring, had these Experiments been made in a Place fully exposed to Wind and Sun, the Expence of rising Vapour would have been found to compensate at least the ordinary Return of Rain for a Supply, as later Experiments have sufficiently evinced.

AND here it may be observed, that in still Weather, when this Fleece of vapourish Air happens

happens to be lodged in greater Quantities near the Surface of the Water, both it and all Objects thereon seem to be considerably raised, and even to lie in a Level above the Land. This can proceed only from the Refraction or Bending of the Rays of Light, coming out of a Medium of one Degree of Density into one of another; as may be exemplify'd at any time by pouring a Quantity of fair Water into a Bason, which will then shew a Piece of Money, lying at the Bottom, to an Observer, from whom it was before screened by the Brims of the Vessel: By this Experiment it will, to Appearance, be raised about one third of the Water's Depth.

AND for a like Reason it is apprehended that the Cattle grazing on the *Isle of Dogs*, are sometimes to be seen from *Greenwich* at the Time of High-water, and not when the Water is low. This some have endeavoured to account for, by supposing the *Isle of Dogs* to be raised by the Tide. But 'tis far more reasonable to conjecture, that in still Weather, when this Appearance is most remarkable, that the Vapours issuing from the Surface of the River are raised along with it in the Tides, and so exhibit an Appearance; which, were they immediately removed by the Winds, would not happen.

IN still and sultry Weather, when the Sunbeams seem to act with a great, a general, and an equal Force, on both the Land and Water, the Rise of Vapours is then observed to be more
dull

dull and languid. When they gleam as it were from behind, or thro' a Cloud, and there is something of a Motion in the Air, or a Wind abroad, they rise in greater Plenty. And in very hot Climates, as Dr. HALLEY informs us, they mount in such Abundance, that in *St. Helena*, lying in Latitude sixteen Degrees South, his Glasses for Observation were very often and very soon covered with Water. And even in hot Weather in our own Climate, the Dews, which are no other than Vapour condensed, are found sufficiently copious. Morning and Evening, in that Season of the Year when the Sun is not far above the Horizon, the rising of Mists from Rivers, Pools and moist Places is frequently very visible, and is generally the Fore-runner of a sultry Day. As the Sun gains a greater Height, the continued Rise of the Vapour is indeed not so apparent; but as the Cause of their Rise, *viz.* the Heat, increases, there is no Room to suspect, but that the Effect is still proportionable to it.

It has been Matter of Dispute among Naturalists, how the Waters which form the Clouds, and which descending, often deluge over vast Tracks of Land, come to be exhaled from the Earth and suspended in a Fluid so much lighter than Water, as is the Air. Some have imagined, that the Particles of Fire, separated from the Sun-beams, adhering to those of Water, make together little Masses of Matter lighter than Air, and which therefore rise therein till they come to such a Part of the Atmosphere as is specifically, or Bulk for Bulk
of

of the same Weight with themselves; there forming a thin Cloud. And they suppose that Rain is produced by the Separation of those Particles of Fire, on Occasions, from them; whereupon they coalesce, and then descend according to their own Gravity, in Drops of Rain or Dews.

THIS Hypothesis, as Dr. DESAGULIERS justly observes in the *Philosophical Transactions*, is not without Objections. As First, Fire has never yet been proved to be a distinct Element, or a particular Substance; and the Change of Weight of Bodies in chemical Preparations heretofore presumed to rise from the Adhesion of Particles of Fire, is proved by Dr. HALES, in his *Vegetable Statics*, to proceed from the Adhesion of Particles of Air, which he has there shewed to be absorb'd by some Bodies in good Quantities, while it has been generated as fast by others; and that it may even be absorb'd and generated successively by the same Body under different Circumstances. Secondly, Should the above-mentioned Supposition be allowed, the fiery Particles joined with the watery must be of some considerable Bigness, and a Person passing thro' a Cloud, in ascending a Hill, must be sensible of an extraordinary Degree of Warmth, which does not happen; for the Vapour is there found to be really colder than Rain itself falling at the Foot of the Hill. Besides, the Manner in which these Particles of Fire might be separated from those of the Water, is to be conceived from no Phænomena yet observed.

This

This Theory therefore seems to be without Foundation.

THE second Opinion concerning the Rise and Suspension of Vapours is, that tho' Water be specifically many times heavier than Air, yet if the Surface of it be increased by greatly diminishing the Bulk of its Particles, it cannot easily fall; since the Weight of each Particle is known to diminish in Proportion to the Cube of its Diameter: whereas the Surface to which the Air resists, decreases only as its Square: And this is sufficiently evident from the floating of Dust, Motes, and other light Bodies, for a Time therein, according as they are more or less minute.

THIS, however, will not explain the Matter before us to Satisfaction; because, tho' the Increase of Surface, the Weight continuing the same, may in great measure hinder or retard the Descent of very small Bodies in the Air, on account of its Resistance to a Surface, so much in Proportion larger than their Bulk, as aforesaid, it will for the same Reason also impede their Ascent therein. And 'tis known that the rising of Dust, &c. in the Air, is owing always to some outward Force or Motion apply'd; whereas Vapours continue to rise as well in calm as windy Weather, tho' not in an equal Degree; neither do they always fall to the Ground, or subside therein, when the Wind ceases.

THE third and most received Opinion concerning this Matter is, that by the Action of the
Sun

Sun on the Surface of the Water, the aqueous Particles become formed into Spherules or Bubbles, filled with an *Aura*, a much finer Air, or one highly rarefied, which thus becoming specifically lighter than common Air, must therefore rise therein by hydrostatick Laws, till such time as they meet with such an Air as is Bulk for Bulk of their own Weight.

THIS seems indeed to be the more probable Supposition of the three; but to support it, the following *Queries* must be answered. How comes the *Aura* or subtle Air within the Bubbles to be at all specifically lighter than that without them; since the Sun's Rays must be admitted to heat the one equally with the other, and to beat with equal Strength on every Part of the Surface? Was it possible, that a rarer could be thus separated from the ambient Fluid, what should hinder the cold Air, which they needs must meet with in their Ascent, from reducing these Bubbles by contracting their Contents; just as Bubbles of soaped Water commonly are, notwithstanding their Tenacity is much greater than that of common Water, when blown up by warm Air from the Lungs? And again, Was it reasonable to admit the rest of the Supposition, a considerable Difficulty will yet remain, *viz.* if Clouds were thus constituted of Shells of Water filled with Air, in its own Nature elastic, why should they not always expand, when the circumjacent Air is rarefied; and why not be condensed, when the Weight of the Atmosphere

mosphere is occasionally increased? This must be the natural Consequence of this Hypothesis, and the Clouds will sink and rise in the Atmosphere on every Alteration of Weight therein, without affording us any Rain at all.

THE Doctor then plausibly proposes another, whereby he endeavours to account for the Rise and Suspension of the Vapours in the Atmosphere, from the Elasticity and Repellency observed in the Steam of boiling Liquors, capable of extruding either Air or Water from any Vessel; and supposes the Repellency of the Particles of Vapour to be always in Proportion to their Degree of Heat. Hence he calculates the Force of the Vapours raised, taking, with Sir ISAAC NEWTON, the Heat of boiling Water at 34, (when the Thermometer will shew our Heat in the Summer to be 5, in Winter 2, and in Spring and Autumn 3 of those Parts) and computes the Height to which they accordingly must rise, comparing their Elasticity with that of the Air, on which Heat has a much less Effect; since that Degree of Heat which will expand Water fourteen thousand times in boiling, will rarefy Air only two thirds. He next considers the Effects the Cold found near and above the Earth must have in condensing those Vapours, and forming the Clouds; and thinks that the Distance they are observed to float at from the Earth, in the various Seasons of the Year, corresponds with this Theory.

BUT

BUT neither does this seem to be absolutely free from Objections. For in Distillations, the Liquor boiling in the Still, over a brisk Fire, raises a great Quantity of Steam into the Head, which endeavours to make its Way immediately down the spiral Pipe or Worm, usually set in a Tub of Water, which, being cold when the Still begins to work, condenses the rising Vapour very fast. As the Water next the Worm comes to be heated by the continued rising of the burning Steam, it condenses it indeed something slower; but yet when this Water is become so hot, that a Man can scarce bear his Hand in it, it will nevertheless continue to condense them into a grosser Fluid apace.

Now as the Mitigation of the Heat of Vapour, and the lowering it from that of boiling Water is generally attended with this Effect, and as very little Vapour is raised in the Still before the Liquor actually boils; it may be presumed, that the Repellency of the Particles of Steam, under the Degree of a boiling Heat, can be but inconsiderable in promoting the Rise of Vapours to any great Height in the Atmosphere, or of producing the Thing proposed.

BESIDES, Steam of any Heat whatever, if it be not some how confined, and caught as it were by some Object near at hand, but being let into the Air loose, like that rising from a seething Pot or slaking Lime, as far as we can trace it,

it, that is, so long as it continues visible, does not by its Motion shew any great Disposition or Tendency towards rising steadily, briskly or the shortest Way, into such Part of the Atmosphere as may be of equal Gravity therewith: But it rather seems vaguely to fly hither and thither, till it can be absorb'd and received by the Air, thereby warm'd in the same Manner as the Breath from the Lungs and other humid Vapours are, as mentioned *Page 240*, of this Treatise.

It might be also suspected, that the Repellency which should give the Particles of Water their first Rise into the denser and circumambient Air, would increase in Air more rare, in their Ascent, and defeat, and by their undue Separation prevent their being ever condensed in Rain. Besides, as the Pressure of the denser Air near the Earth is not able to reduce them into so close a Contact as to form Drops of Water there, it is not likely that in a rarer Medium this should be done with more Success.

FOR Want therefore of a more perfect Theory of this Part of our Meteorology, we must at present, in good measure, content ourselves with observed Facts. And it being evident, that rare and warm Air, together with what humid Particles it shall at any time imbibe (and which from the constant Heat of the Sun must necessarily constantly be done, and that in very great Plenty) will emerge and swim in Air

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that's dense and cold, to such Part of the Atmosphere as is of equal specifick Gravity therewith: And that whenever, for want of the superincumbent Pressure, a Part of its Density shall be lost, it will let the watery Particles fall, and they being collected and assembled in good Quantity, will at length perhaps form a floating Cloud, and become visible, merely by the Reflexion of the Rays of Light, which, falling by various Angles thereon, exhibits various Colourings, and a Multiplicity of Forms, to the Eye of an Observer: Or if its Density shall continue to be still more diminish'd, it may be again resolved into its original Water, and become an immediate Shower of Rain.

THE Sun shining with equal Strength on the Surface both of the Land and Water, will doubtless affect them differently: Because a great Part of his Rays are reflected from the solid Earth by the same Angle in which they fall thereon, whereby the Air will always be more rarefied over this, than over the Water, which absorbs most of them, and reflects but few: Of consequence then the light Air will mount, and continue to rise over the Land, and the dense and vaporous Air from Sea will croud after it, to make good the Deficiency; as in the Case of the Land and Sea-breezes, was before explained, *Page 256*; and hence abundant Matter will probably there be collected towards the Formation of a Cloud.

IF then the Season be inclined to wet, and especially if there be an Eminence upon the Island (round which the Air will always be colder, and therefore denser than over the Campaign, the Sun-beams being thereby diffipated in a great Variety of Reflexions) the thinner Air charged with Vapour, as before, will stream thither from every Quarter, and mounting its Sides, like Smoke up a Chimney, will soon envelope, and hood over its Top with a Cloud: And should this Disposition of the Air to Wet continue, the Vapour will continue rising in this Manner, and condensing so fast, as till it becomes a heavy Rain in all the Parts adjacent.

AN Appearance of this Sort on the Top of Hills, the *Pike* of *Teneriffe* particularly, is not uncommon. The Mariners also often observe a very small Cloud at first, which they therefore call the *Bull's-Eye*, gathering over a small Island in the Ocean, which frequently increases so fast, by the Accession of light and humid Air from the Water, that it fills the whole Hemisphere very soon with Rain, frequently attended with a Tornado of Wind, Lightning and Thunder; and the Storm is doubtless more or less violent, according as Quantities of Matter happen thereabouts to be amassed for the Production of each sort, as aforesaid.

AND here it may be remarked, that in Storms of this kind, the Wind is observed to blow

all round from the Place where it rages most; which is a plain Intimation, that these extraordinary Commotions in the Air are really produced by the Explosions of Matter meeting therein, and disagreeing in the Manner heretofore proposed, *Page 264*, whereby a different Direction is given to the Body of Air adjacent, being driven thence all round, as from a Centre.

AN Experiment to prove our Hypothesis for the general Formation of Clouds over Islands, Promontories, Capes and the Sea-coasts probable, may be thus made. Take a large Dish, fill it with cold Water; into the middle of this put a Water-plate filled with Water warmed. The first will represent the Ocean drinking in the Sun-beams falling thereon, the last an Island reflecting them, and so heating the Air above it more. Blow out a Wax-candle, and if the Place be still, on applying it successively to every Side of the Dish, the fuliginous Particles of the Smoke being visible and very light, will be seen to make toward the Plate, and rising over it, will point out the Course of the vaporous Air from Sea to Land. Again, if the ambient Water be warmed, and the Plate filled with Water cold, let the smoking Wick of the Candle be held over the Centre of the Plate, the contrary will happen; and a Demonstration thereby be also given of the Cause and Consequences both of the Land and Sea-breezes before-mentioned.

WAS the Globe of the Earth one plain watery Surface, and had the Sun, as now, his apparent diurnal Motion round it, a certain Quantity of Vapours would then be daily raised and retained by the Atmosphere. These Vapours, when the Air came to be condensed on Nights, would, 'tis probable, as constantly subside and sink in Dews; as Salts will often precipitate to the Bottom of Liquors overcharged therewith, when they come to cool: Nor in this Case could any Diversity of Weather be expected, other than periodically, and every Year alike.

BUT let this general Ocean be supposed interspersed as it is with spacious Tracks of Land consisting of various Soils, and various in Form, whence Emanations may also rise, not merely of the watery kind, which by their Diversity, as before explain'd in Case of the Winds, may occasion Variety of Weather: This Land, of different Altitudes, and in particular Places, strew'd with high Mountains, such as the Pyrenean, the Alps, the Apennine, and Carpathian Hills in *Europe*; *Taurus*, *Caucasus*, *Imaus*, and others of Note in *Asia*; *Atlas*, and the Mountains of the Moon, with other Ridges in *Abyssinia*, and the less known Parts of *Africa*; and in *America*, the *Andes* and *Apalatean* Mountains; all far surpassing the usual Height to which the watery Vapours ascend, will cause a considerable Difference: For these by their Eminence and Situation, either collect

humid Particles from the adjacent Seas and Plains, as explained, *Page 307*, or intercept them, being transported thither by the Winds, where mounting up the Sides of the Mountains with the Stream of Air, are there frequently dashed together, or so condensed, that coming within the Reach of each other's Attraction, they run together, and forming larger Drops specifically heavier than the ambient Air, immediately fall in Rains and Dews; or else settling all round the Eminence, gutter and gleet down the Surface of the Stone, and uniting, often form a Rill; and several of which collected in a common Channel, make a Brook; Variety of these a Stream; and an Assemblage of Waters from a Diversity of these, after draining perhaps a vast Extent of Land, may become a River, like the *Rhine*, the *Rhone*, the *Thames* or *Danube*.

IN order to estimate the Quantity of Water raised in Vapour from the Sea, and to compare it with the Returns made thither by the Rivers which conduct it back, Dr. HALLEY has curiously considered the *Mediterranean* Sea, into which nine very considerable Rivers, viz. the *Ebro*, the *Rhone*, the *Tyber*, the *Po*, the *Danube*, the *Neister*, the *Boristhenes*, the *Tanais*, and the *Nile*, are continually emptying themselves, besides the Supply always coming into this Sea from the main Ocean, thro' the Straights of *Gibraltar*, without raising the Waters therein one Jot,

He judges the Extent of the *Mediterranean* to be about one hundred and sixty square Degrees, forty long and four broad, and thinks that each of the above-mentioned Rivers affording about ten times the Water discharged by the *Thames* in a Day, may be adequate to that brought in by the ten large Inlets of Water before-named, that is, eighteen hundred twenty-seven Millions of Tuns *per Diem*. And from a nice Experiment he made on some Water salted to the same Degree with that of Sea-water, which he evaporated with Care over a gentle Fire, whereby he brought the Heat thereof up to that generally found in the *Mediterranean*, of which he was able to judge by help of a Thermometer, he calculates, that in serene Weather there must be at least five Thousand two hundred and fourscore Millions of Tuns exhaled thence in a Day; and in windy and troubled Weather much more. Some Part of this is allowed often to sink therein again in Rains and Dews; but far the greater Part is either transported by the Winds, or is inclined to draw toward the adjacent Lands, as has been said, to water the Productions of the Earth; all which may without Difficulty be traced back to their original Water. Of this a good Part indeed remains still in a fluid State, and is therefore capable of being again circulated on Occasions for the Purposes before said; but a no inconsiderable Part has been thought by modern Philosophers of principal Note, to become fixed, and absolutely lose its Fluidity.

WHAT gave Birth to this Opinion was this: A Quantity of Earth was sifted, put into an Oven, well dried, and then weighed. This has been afterwards put carefully into a Tub, and a Plant weighing perhaps four Ounces, has been set in it, which being well watered, has in due Time grown up to a Tree weighing perhaps an Hundred Pounds. This being taken out of the Mould, the Mould has been again dried and weighed, as at first, and the Weight thereof found not in the least diminished. Now as the same must constantly happen to every Thing produced by the Earth, Fossils as well as Vegetables, the Solids have been thence judged hourly to increase upon us, the Fluids to decrease, and the Sea-water consequently to grow more and more distasteful and bitter. So that in a great Length of Time, the Earth is apprehended to be in Danger finally of losing all her Fluid, and of becoming a sapless Mass, such as in all Probability is the Moon: Since no visible Alteration or Change has ever appeared on her Face view'd from the Earth, whereby she might seem in any Part more clouded, as to the lunar Inhabitants, if such there be, must frequently have happened with respect to the Earth; on which it has frequently rained in different Places for a long Time together.

Tho' the Instance last mentioned be true in Fact; yet it must be admitted, that far the greater Part of whatever Bodies are thus produced by the Fixation of our Fluids, does
again

again resume a fluid State in case of a Dissolution, to which they are sooner or later all subject; and in so doing their humid Particles must again mingle with the Air, and circulate as before. The Ashes, for Example, when our before-mentioned Tree comes to be burnt, or the remaining Dust, when its Parts come to be disunited and dissolv'd by Time, are but insignificant in point of Quantity: Whereas the fluid, and by far the more considerable Part, rise again into the Atmosphere; in the former Case, in the Form of humid Smoke; and in the latter, with other Vapours exhal'd from the Earth.

BESIDES, that elementary Water may be changed from a solid to a fixed State, is not so easily proved as some have thought. It is certain, that common nutritive Water is a very heterogeneous Substance, having in it Air, Salt, Oil and Earth. In Proportion as Water is freed of these Ingredients, by Distillation or otherwise, we learn from Dr. WOODWARD'S Observations, that it becomes less fit for the Nutrition of Plants: And we find from the same Observations, as well as from those of Doctor HALES, what a vast Quantity of Water Plants require for their Increase and Well-being. How then can we be certain, that the earthy and other fix'd Parts of Vegetables, are not composed of some of the fixed and earthy Parts of the nutritive Water; the rest of those Parts flying off along with the true watery Element, in the Course of their very copious Perspiration? So that a Plant may easily ac-

quire a great deal of fixed and solid Matter, without any sensible Diminution of the Earth it stands in. Or at least what Part of that Earth or other solid Principles may be carried up into, and consolidated with it, may be again supplied by new Earth, deposited from the Water wherewith it is moisten'd from time to time. If this then be the Case, as it seems very likely to be, we need be under no great Apprehension of our Earth's losing all her Fluids, and so of becoming unfit for the Habitation of Men and other Animals. Nor shall we need the Assistance of Comets and their Effluvia, to renew from time to time this daily Waste of fluid Matter, which Sir ISAAC NEWTON thinks necessary in his *Principia*. But whether the Motion of the Earth, and other Planets, might not be considerably altered by such copious and frequent Accessions of foreign Matter, might seem, among other things, to be a Point worthy Consideration.

*On the ORIGIN and SOURCE of
SPRINGS.*

IT has been already hinted, that the Hills are of singular Service to Mankind in collecting the Particles which thence descend into the lower Lands, and water the Earth. There are in the World numberless Instances of this kind. *Mercator* says, that toward the middle of the Island of *St. Thomas*, there is a Mountain well stor'd with Wood, which in that hot

hot Climate is always cover'd with thick Clouds, even when the Sun is in the Meridian; whence proceed gentle Streams, sufficient to water all the Sugars in the Plantations. It may therefore reasonably be presumed, that those humid Particles which in these Places do neither fall in Rains, or trickle down the Out-sides of the Hills, are percolated by degrees thro' the Pores of the Earth, and pass along the Crannies of the Stone, &c. till they find their Way into subterranean Reservoirs; which being thus successively supplied with Vapour condensed, may cause them to overflow, and thereby feed the Springs that more frequently break out of the Sides of these Eminencies, than in any other Place. And thus may the Circulation of Moisture be imagined to be carried on progressively between the higher and the lower Parts of the Earth, in a more reasonable Manner, than by supposing, as some do, either, First, That Springs are the Result of Rain-water only, tho' they flow continually, and often without Diminution in the driest Seasons, and when no Rain has fallen for a long Space of Time; or, Secondly, That they are derived from a Filtration or Percolation of the Seawater, thro' certain imaginary Tubes or Passages within the Earth, in doing whereof they are, with no great Probability, said to lose their Saltness: Which, besides many others, labours under this Absurdity, *viz.* That some of the greatest Rivers in the World have their most copious Fountains farthest from the Sea, and often at such a Distance, that it is hardly credible,

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credible, so vast Quantities of fresh Water should so luckily find a Way thither by the Means above proposed.

IT is improbable, for Instance, that such a River as the *Nile*, whose Source is some hundreds of Miles from any Sea, in a high and mountainous Country, and in the middle of the torrid Zone, should at periodical Times roll down first a great Quantity of turbid Water, and fill his spacious Bed, and this be followed by such a Flood, as lays a flat Country, of so large an Extent as *Egypt* is, under Water; from which Advantage it becomes indeed a sort of Granary to the East, and without it might probably be as barren as are its neighbouring Desarts.

THE Attraction of Cohesion ordinarily ad-
duced in the Case of Springs, bears no Pro-
portion to these Effects. If this Cause be con-
tinual, it is doubtless uniform. Whence then
comes it, that the Inundation here mentioned
is periodical? Rain in that Country cannot be
the Cause: *Egypt* is too well surrounded by
large Continents to get much Rain. But it is
not unreasonable to believe, that the Source of
this famous River lying near the Foot of the
Mountains of *Abyssinia*, which, when the Sun
is near the North Tropick, and the Wind con-
sequently North-easterly, collect and condense
the Vapours directed thither from the vast *In-
dian* Ocean, when the rainy Season in those La-
titudes usually begins; and hence may proceed
the

the Deluge of Rain, which rolls down into the flat Country, and produces the before-mentioned great Effect.

NOR is it utterly improbable, but that those very Mountains, tho' they are situated in the torrid Zone, may, like the *Alps* and other like Eminencies more Northward, be covered with Hail and Snow at proper Seasons, which by the Increase of the Heat upon them, and especially when the Sun becomes vertical, may melt pretty suddenly, and produce, or at least promote, this periodical Inundation.

AND this seems the more likely, since People who cross the *Alps* in *July* and *August*, are sensible of all the Change of Seasons in the Year, and that often in the Compass of ten Miles riding. At the Top, when beyond any great Reflection of the Sun-beams from the general Surface of the Earth, they seem to be in *Greenland*; toward the Middle the Weather grows milder, where they meet a kind of Spring; and at Bottom they sweat under the Violence of the Heat.

As there are sundry Places of the Earth where it seldom or never rains, so there are others where it is almost always Dripping. The first are extensive Flats, where there are no Hills to intercept and stop the Moisture floating in the Winds; the other are mountainous Places, that catch all the Humidity that comes in their Way. Hilly Countries therefore

fore never want an over Proportion of Rain, for which they often, indeed, rob their neighbouring Plains.

THE Design of the Hills then in general seems to be, That they are placed by Providence commonly about the Middle of the several Continents, that they might serve to stop, or at least to collect, fresh Water, for the Support of vegetable and animal Life in the adjacent Countries. By their Height they are also of signal Use and Service in giving the proper Descent to the Streams thus produced, to the End that they may flow gently, as the Fluids in the Vessels of the Body do, thro' every Part, in order to render them of more general Use and Benefit : And from the extraordinary Pressure of the subterranean, descending Waters, probably, proceeds the free and plentiful Rise of Springs in Wells dug in lower Grounds.

AT the same time, however, that we ascribe the principal Origin of Springs to the general Circulation of Vapours, we cannot but observe, that some of them are temporary, others perennial. The first flow plentifully in moist Weather, and then are often long dry ; the other issuing from the Bowels of no great Eminencies perhaps, yield constantly, even in the greatest Droughts, an equal Quantity of Water. This can only proceed from their being happily furnished with a constant Vein of that Fluid, thro' subterraneous Passages leading

ing from the Parts adjacent, and higher situated, to the Place of its breaking forth. Nor can it be denied, but that Vapours may, by the Heat of the Earth only, when not exposed to the Winds, rise from the Bottom of the Caverns, sometimes found in the Belly of huge Hills, as in an Alembic, especially if near the Springs, where being slowly condensed above, and trickling gradually down the Sides, may from time to time replenish certain natural Stone Reservoirs, often to be found within such Hills (something of which sort in particular may be observed in *Pools-Hole* in *Derbyshire*) whence they glide on the first Bed of Clay or tenacious Earth they meet with, to some convenient Aperture, thro' which they make their Way.

On HAIL, SNOW *and* FROST.

HAIL appears to be no other than Drops of Rain congealed by the Cold, always found in the upper Regions of the Air, beyond the Reach of the Reflection of the Sunbeams from the Earth. Being opened, there appears somewhat like Snow, of a looser Contexture than Ice, in the middle of the Hailstones, and the rest seems to lie one concentric Kernel upon another. They often differ pretty much in Size: The larger Sort, by the Violence of their Fall, shew they come from a great Height; and tho' at the first Outsetting

setting their Bulk might not perhaps exceed the ordinary Size of common Hail, yet in their long Journey, supposing the humid Medium, thro' which they pass'd, inclined alike to Congelation, they probably increase their Bulk throughout their whole Passage. And that they do so, by the Accession of freezing Vapours, appears in part by their being commonly of a looser Texture than Ice.

HAIL is a frequent Attendant on Thunder and Lightning; whence it may be conjectured, that the Salts in the Air, then probably abroad in greater Quantities, contribute in great measure to the Congelation thereof. That Nitre, and several other penetrating Salts, will produce a like Effect on Water, will appear on mixing a Quantity of them, or even common Salt, with some Snow or Ice pulverized. In this Mixture, dissolved before the Fire, immerse a Bolt-head full of common Water, which presently freezes, even in warm Air. The Experiment is described *Fig. 12. Plate 9.* The Bolt-head *AB* is filled with Water only to *C*. This immersed in the before-said Solution will, from the sudden Constriction of the Glass, first meeting with the Cold, immediately rise in the Stem, perhaps to *D*. Soon after it will gradually descend from that Point, condensing till it comes down, and settles perchance at *E*; where for sometime it will remain at Rest: But soon recovering itself, and beginning to expand, it will gradually rise from *E* to *F*, and thence soon after, by one Leap, to *G*. The Water
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in *A* is hereupon seen thick and cloudy, and that Moment seems to be converted into Ice. As more of the Water in *A* however becomes congealed, and the Ice hardens, part of the Water will overflow at *B*, in order to give it Room to do so. Whence it appears, that all Fluids subject to freeze, (except Oil, which alone is more contracted in freezing) become specifically lighter, from Observation, about a ninth Part; all inferior Degrees of Cold however will make them seem specifically heavier by Contraction: For this Reason it is, that Ice not confined always floats on the Surface of Water.

It may here also be remarked, that a Quantity of Water, before and after it has been frozen, is found by Experiment to differ considerably in Weight; whence it may be concluded, that the Evaporation ceases not, either when the Water is freezing, or even when it is in a State of Ice: Which inseparable Quality of Ice renders it difficult to say, whether frigorific Particles, which deprive Bodies of their Heat, if such there be, have any Weight or not.

THE Principle which Authors have gone upon, in order to solve the Phenomena of Freezing, are either, First, according to GASENDUS, that some foreign Matter is introduced into the Pores of the Fluid, by Means whereof its Bulk is increased, and its Parts become fixed.

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AND these Gentlemen, to solve it, apply to certain nitrous Particles, properly formed to produce this Effect; in regard *Sal Ammoniac*, Saltpetre, Salt of Urine, and many other volatile and alkalizate Salts, mixed with Water, increase its Degree of Cold very sensibly. And the Manner in which these Particles are presumed to hinder the Fluidity of Water is, that they are constituted of rigid pointed *Spicula*, easily, they say driven into the Globules of Water, which, being variously mingled, and as it were intangled together, by Degrees enfeeble, and finally destroy the Motion thereof.

SECONDLY, The Followers of DES CARTES assert, that some Matter, naturally contained in the Fluid, is by an intense Degree of Cold expelled, thro' the Absence of which, the Body becomes fixed. And this they presume to be brought about by the Recess of the active ætherial Matter, to which they ascribe all Motion of Bodies, out of the Pores of the Water, or at least to a very large Abatement of it. And considering the known Phænomena of the Freezing of the natural Fluids (the Attraction and Repulsion of whose Parts in a State of Fluidity are pretty near equal, and therefore easily moved one among another, as also from the Melting of such as are only reduced to a State of Fluidity by Heat, the Parts being put under a Degree of extraordinary Vibration, which by Cold again become rigid, wherein the Attraction of their Parts seems

great

greatly to overpower that of their Repulsion; whence proceeds what we call Cohesion, Tenacity, Viscidity, and the like) we cannot refute either of the Systems above-mentioned, since neither of them at present come under Proof by any Experiment: They are therefore purely hypothetical.

BUT the third Opinion on this Subject, according to a late *French* Author, is, That there is some Alteration produced in the Texture or Form either of the fluid Particles, or of something contained in them.

IN Favour of this last, it may be observed, That a Globule of Water held on the Point of a Needle, in a smart Frost, will, upon freezing, shoot itself out into a Star, having a certain Number of Points; and Snow, which is a frozen Vapour, seems to be no more than a Congeries of these Stars, united to each other by the Tips of those Points, and by no means adapting themselves to, or filling the Interstices between them: It must thence follow, that the Dimensions of a Quantity of Water, reduced thus by Cold from a fluid to a fixed State, will be considerably enlarged. Nor are any Pipes or Vessels strong enough to resist the natural Power of the Congelation, but they generally burst whenever the Fluid therein confined happens to be frozen: And a Force capable of making a Gun-barrel fly, will be easily admitted gently to heave the Earth or Soil in a Frost, thereby rendering it more light,

that so the Fibres of Plants may afterwards be able to shoot therein with greater Freedom; whence may probably proceed the general Fertility of such Summers, with us, as succeed hard Winters; not to insist on the Destruction Frost usually brings upon the *Ova* of Insects, and other noxious Animals.

It may farther be observed, in favour of this last Opinion, that Ice being never so transparent as Water, the Rays of Light do not pass thro' Water congealed and fluid in the same Manner: Which seems to imply, that the Contexture and Connection of the Parts of this Fluid are changed, and, in these Circumstances, otherwise combined; for Snow, wherein this Change of Parts is most remarkable, is still far more opake than Ice. At least it is an Evidence, that there is an uneven Mixture of an infinite Number of Air-Bubbles, and those various in Size, with the Particles of congealed Water, which will also hinder its Transparency.

If we look warily among the regular and intire Flakes of Snow, as has been said, we always find them constituted of Rowels of six Points, adhering to each other by the Ends of those Points; sometimes however they appear in broken Points and Parcels, that seem to be only Fragments of the regular ones; and some there are that seem to be wholly unform'd. This probably proceeds from the Accidents they may have met with in their Descent to the Earth.

Earth; as, by various Winds in their Passage, they may be first thaw'd and then frozen perhaps again, and so occasion this seeming Irregularity.

THO' Snow seems to be soft, it is truly hard as Ice; and did not the Points melt on the Approach of the Finger, or yield under it, they would appear so to the Touch, as when it is crushed by the Foot, it really does. It is however very light, on Account of the extream Thinness of each Icicle, and of its large Surface in Proportion to its Weight; and Gold, tho' the most ponderous of Metals, will easily ride on the Air, we know, when beaten into thin Leaves.

SNOW is white, because it consists of Parts that singly are transparent; but when they are mixed together, they appear white; as do the Parts of Glass, Froth, and other diaphanous Bodies, whether soft or hard.

On SOUNDS.

SOUND is itself not a Body, but a Motion, accidentally impressed on the Body of the Air, by the Tremors of sounding Bodies, excited either by Percussion or the like. It is a Motion very different from that of the Winds, which consists in the local Motion of the Air, or a Stream of it flowing successively, without the least Vibration; whereas Sound is conveyed

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veyed by such a Motion of this Fluid, as is incapable of producing any Repetition thereof in the same Place ; but having once floated along the Medium by the Ear, the Sound seems to drop at once, and be thenceforward there wholly lost, unless it be afterward reflected thither.

THE Motion of the Air in the Winds will act vigorously on Flame ; but it affects not the Ear with Sound, unless it meets with some fixed Object, the Resistance whereof causing a Vibration therein, it then becomes audible. But the Agitation of the Air, in the Case of Sounds, gives no Motion at all to Flame : For a lighted Candle put near a great Bell, when made to sound, will not have its Flame agitated in the least thereby.

SIR ISAAC NEWTON, according to the received Notion of this Truth, also demonstrates, in the 43^d Proposition of the 2^d Book of his *Principia*, That Sounds, as they rise from the tremulous Motion of elastic Bodies, are nothing more than the Propagation of a Pulse in the Air shaken thereby : And this is confirmed by the great Tremors that strong and grave Sounds, as the Report of Cannon, or the Sound of great Bells, excite in Bodies all round them. And he concludes, that Sounds do not consist in the Motion of any Æther, or finer Air, as some have asserted, but in the Agitation of the whole Body of the grosser Air contiguous ; because by Experiments we find, that the Motion of Sounds, and their Propagation, depends

depends absolutely upon the Density of the whole Air.

To prove this ; if we put a sharp-noted Bell under a Receiver, and ring it, it will be heard to a good Distance ; exhaust the Air, and make the Clapper strike against the Sides, the Sound will gradually abate ; and when the Atmosphere is quite removed, it will scarce be heard at all. Again, if the Air be condensed in the Receiver, the Sound will grow louder and louder, in just Proportion to the Degree of Condensation, or the Quantity of Air crouded in.

NOR does this happen only in forced Rarefactions and Condensations ; but in such also as are natural : As is evident from FREDLICIOUS's Account given in VARENIUS's Geography, of his Journey to the Top of the *Carpathian* Mountains in *Hungary*, said to be higher than the *Alps*. Here the Atmosphere, on account of the Abatement of its Height, with regard to the Sea and lower Parts of the Earth, must be very much attenuated ; and the Explosion of a Musquet there fired, seemed to him to sound but like the Breaking of a little Stick.

It may also here be remark'd, that in misty Weather, when the Air is loaded with Water, or floating Vapours, being Parts of an unelastic Fluid, Sounds seem to come heavily to the Ear, and much altered from what they seem, from the same Objects, when the Air is clear.

THE Sound of the Bell, continually sensibly increasing on the gradual Re-admission of the Air into the Receiver, plainly shews, that the Quantity of Sound depends on the Degree of the Condensation. Mr. HAWKESBEE's Experiments on Sounds made in the condensing Engine, put this Matter also beyond all Doubt; and such Persons as at great Depths of Water, in the Diving-bell, have their Atmosphere very dense, and of Consequence very elastic, at the ordinary Pitch of Speaking seem to give very high Words; and a Person who attempted to blow a Hunting-horn in that Situation, had like to have stunn'd both himself and Hearers.

THIS can only proceed from the Parts of the elastic Fluid, adjacent to the sounding Body, being thereby put in Motion, which immediately thereupon catch and communicate Motion to those which lie nearest, these to the next, and so forward, tho' more and more faintly, till by the Distance from the Centre of Sound, or the Inactivity of the Matter, in the Course of its Progress to be moved, the Resistance will at length be equal to the Impulse, and the Motion therefore be no farther propagated. Much as a Stone thrown into Water, will therein immediately raise a wavy kind of Motion, shewn by the concentric Circles, continually floating off, but growing less and less conspicuous, till they impinge or strike against the Bank if near, or finally disappear of themselves, if the Surface thus put in Motion be over-large. It
must

must only be observed, that the Tremors of the elastic Particles before said will be propagated from the sounding Body, in all Directions, as from the Centre, to all Parts of a surrounding Sphere.

FOR this Reason, the Organs of Hearing, that are equally sensible and good, are equally affected by the same Sound, convey'd to them from equal Distances; and at different Distances they are by it differently affected, receiving it in a different Manner. For Instance, a Person, at the Distance of two Miles, may hear *St. Paul's* Clock strike without any great Emotion; but at the Distance of ten Yards it would give him a good deal of Surprise. The Collision of the Bell with the circumjacent Air will be there very violent; but farther off the Motion will become moderate and more languid. And

THE Blow on these Occasions given to the *Membrana Tympani* will be successively propagated thro' the artful Meandrings of the Ear, till at length the auditory Nerves will be more or less shaken thereby, and the Sensation of Sound will to the Perception be conveyed, in Proportion to the Degree of the Impulsion given; upon which alone the Variety of Sounds wholly depends.

IT may not here be amiss just to hint, that in the Process of Hearing there is a two-fold Impulse given to the auditory Nerves, and both propagated from the *Membrana Tympani*. One seems to be by the undulating of the Air in the Cavity of the subjacent *Concha* or Drum
of

of the Ear, which acts upon the Membrane of the *Foramen rotundum*: And this only influences one of the spiral Cavities of the *Cochlea*. The other Impulse is made with wonderful Contrivance and exquisite Art: The Tremor of the *Membrana Tympani* being propagated all along the five small Bones of the inner Ear, some of which are moveable, to the Membrane of the *Foramen ovale*, which opens into the *Vestibulum* or Porch, whence alone the sonorous Motion is communicated to the Nerves, which are very artfully distributed along the other spiral Cavity of the *Cochlea*, and its three semicircular Canals.

THE most elastic Bodies are the most sonorous; therefore Bell-metal, Glass, and the like, are remarkably so: But nothing more than a well-stretch'd String. This being struck, will sound a considerable Time, vibrating this Way and that, crossing the Line at each Vibration, as a double Pendulum would do. Its Motions in this Case are described *Plate 9. Fig. 13* wherein *AB* is the Direction of the String before it is struck, and *ADB* and *ACB* the Figure it will form after. These Vibrations are greatest just after the Stroke, the greatest Range being made by the Middle of the String, and from the Counter-action of the two fixed Points *A* and *B*, and the Resistance of the Air it strikes against at each Vibration, the String at length ceases to move or sound.

FATHER MERSENNIUS says, he found by certain Experiments, that a String extended till it was of a Concert Pitch with the Note *C faut* in the Middle of the Base Cliff, made no less than an hundred and four Vibrations in a Second of Time, which consequently gave as many Impulsions to the ambient Air; but were so swiftly performed, even here, toward the Bottom of the *Gamut*, where the Vibrations are beyond Comparison slower than they are above, that the Ear was not so perfect as in the least to distinguish the Intervals thereof: But as in whirling a live Coal round pretty fast, tho' we know it changes its Place successively, and every Moment, yet it appears to the Eye to describe one continued Circle of Fire; so are we apt to judge that to be a Continuity of Sound, which in Effect is the Consequence of several distinct Strokes or repeated Impulses from the sounding Body. And Sir ISAAC NEWTON shews, in the Corollary of his 48th Proposition, *That the Number of Pulses propagated, is always the same with the Number of the Vibrations of the tremulous Body; and that they are not by any Means multiplied in their Progress from it.* This also plainly appears, by the immediate ceasing of the Sound, with the stopping the Tremor of the sounding Body, which, in Bells that are struck, is sufficiently plain to the Touch, and in Strings of a grave Tone it is also evident to the Eye.

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THE Difference of the Velocity of the Vibrations of Strings sounding a higher and a lower Note, may be in Part collected from the very great Smartness wherewith the shorter Strings of a Spinnet will throw off a Fragment of Paper, or other light Body, hung loosely thereon; whereas on the longer it will easily ride, at equal Distances from the Jack, when the Strings are made to sound.

THE Manner in which a Stroke acts upon a Bell, is something different from one on a String. The Vibrations of this are made directly across the Line of its Tension; the only fixed Point of the other is that of its Suspension at the Crown, or in the strongest Part of the Bell. The first is a single streight Chord; the other is composed of an infinite Number of Rings, greater or less in Diameter, according to their Distances from the fixed Point. As the longest String, when stretched, vibrates slowest, so do the Rings of greatest Circumference in this Machine: Hence we find that a Bell differs in Tone, according to the Part 'tis struck in. Toward the Top, the Sound will be more sharp; toward the Base, more grave; according to the different Dimensions of the circular Chord, supposed to be struck.

A STROKE on a Bell throws that Machine into an elliptical Form: If it be struck without, the Front and Rear are thrust thereby
nearer

nearer together, the Sides fly out, and the Endeavour of the elastic Matter to restore it self to its circular Figure, vibrating to and again, becoming elliptical as it were, first one way and then another, is what gives and continues the Sound; and if the Blow come from within, the contrary must happen. This will be evident, from striking a glass Bell, fast suspended in a Frame, by the Crown, having a Screw in one of its Pillars, which may be either easily advanced toward the Machine, or withdrawn from it, at Pleasure. The jarring of the Machine against the Screw, when gently struck in Front or Rear, will shew that the Diameter is increased at right Angles to the Direction of the Blow; and its not jarring when struck, in like manner toward, or in the Direction of the Screw, will demonstrate, that the fore and back Side do then fly out, on the first Impulse given.

THE Difference of musical Tones (which are no more than seven distinct, *viz.* the Notes of the *Gamut*; and the whole Compass of Notes above or below these, being no more than a Repetition of the same Notes, either in a higher or lower Key) intirely depends on the different Number of Vibrations, communicated to the Air in a given Time, by the Tremors of the sounding Body. The quicker the Succession of the Vibrations is, the acuter is the Tone; and the contrary.

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THERE are various Ways of making Strings express the Notes in Musick. The simplest Way of doing this, is to extend them with Weights; and if they be of one Length and Thickness, keeping the Series of the square Numbers, viz. 1, 4, 9, 16, 25, 36 and 49, will produce this Effect *. If you would have the Weight or the Extensions all equal, you must increase the Diameters of the Wires or the cylindrical Strings so, that the Areas of their Sections may be in the foregoing Proportion. But the best Way of doing this is, by Stretching or Tension, and then compounding both those Proportions in a judicious Manner, for the sake of Convenience; as is done in the Harp, Dulcimer, Spinet, and Instruments of that Kind; the Strings whereof are extended above, and one End of them fixed over a Cavity intended to magnify their Sound. This is always covered by the Belly, a dry elastic Piece of porous white Fir, left thicker beneath the Treble Strings, and thinner under the Base, that it may by their several Vibrations be more or less shaken, in order, by its Counter-vibration, to moderate the Notes, to mix and meliorate the Sound, and so to give what is called the fine Tone of the Instrument.

A MUSICAL Chord performs all its Vibrations, whether long or short, in the same Space of Time. For if a String be stretched between

two

* The same Reason obtains also in Bells; for if you chuse seven Drinking-glasses all of the same Note and Tone, and fill them with Water in Proportion to those Numbers, they will express the several Notes of Musick tolerably well; but in an inverted Order.

two Pins, and a Force be applied to the middle Point, to draw it out of its rectilineal Situation, if the Distance be but small, 'twill be in Proportion to the Force applied; and consequently the Velocity wherewith it returns, when left to itself, will be as the Space it has to move over; and 'twill therefore perform all its Vibrations, from first to last, in the same Time. For which Reason the same Chord, in what manner soever struck, always produces the same Note. It is also found by Experience, that when Strings of equal Diameter, but of different Lengths, are equally stretched, the longer they are, so much the less Weight will draw them from their rectilineal Situation, to the same Distance; the Forces therefore by which they return are less, the Times of their Vibrations longer, and their Tones are consequently more grave.

WHEN two Chords perform their Vibrations in equal Times, the Tone produced is termed a *Unison*. If one performs one Vibration, while the other is making two; 'tis called an *Octave*. If one make three, while the other two; 'tis called a *Fifth*. If one three, while the other four; 'tis called a *Fourth*. If there be an Interval of two, or if the Vibrations are as 1 to 3; 'tis called a *Third*, &c.

To make an *Unison* Sound, it is not necessary that the Vibrations of the two Strings should actually concur; but only that they should be performed in equal Times, so that they would always concur, if they began at the

the same Instant. For, as it has been observed, the Ear perceives not the single Vibrations distinctly; but only discovers that Difference, which proceeds from the Intervals of Time which pass between them.

FROM these Principles, we endeavour, with a late ingenious Author, to account for the Trembling excited in all the *Unison* Strings of any Set of Instruments in Tune, when any one of them is made to speak: For the Vibrations of the Air, which correspond to the Tremors of the first, agreeing exactly in point of Time with those which are capable of being given to the others, when they have, by their first Impulse, communicated a small Degree of Motion to them, will by conspiring therewith, as they move backwards and forwards, by the same Means continually increase their Motion, till it becomes sensible. And the contrary happens when Strings are in Discord with each other: For in this Case, should one possibly give Motion to the other, yet their Vibrations not being performed in equal Times, the second will come unseasonably, and, when the other is moving the contrary Way, will obstruct its Motion.

IT is farther observable, that all the *Octave* Strings of a Harpsicord in Order, will tremble more or less when any one of them sounds. If one of them vibrates twice, while the other once, every second Vibration of the former will sound a *Unison* with every one of the latter. So if one vibrates thrice, while the other

once,

once, the Intervals of the last will be divided into three Parts, each of which will sound a *Unison* with it, while the two Points between those two Parts will remain at Rest; or otherwise they would interfere, hinder each others Vibration, and not receive from thence Motion sufficient to produce either a Tremor or a Sound. These Experiments are to be made very well on Glasses of Water, rightly toned; because the inclosed Fluid will help to make the Tremors more evident.

THAT Strings thus circumstanced do actually vibrate, and therefore give a Sound in some Degree, will also be sufficiently plain, from observing the Motion of a small Piece of Paper or Down put on the *Unison* or *Octave* Strings of all Instruments in Tune. And the Thirds and Fifths being more nearly allied to these in Point of Tone than any other, something of an inferior Motion may be observed in them, when an *Octave* sounds: These three Notes are therefore called *Perfect Concords*.

Now as a *Unison* String in *Vacuo* cannot this Way have Motion communicated to it, it thence appears, that 'tis the Collision of the sounding String with the Parts of the Medium, put thereby in Motion, which excites a certain Degree of Motion in all those Bodies, that within the Reach of the Sound happen to be in the same Disposition, with regard to Tensity and Tone, to receive that kind of Impulse

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pulse or Impression from it. For Instance; one kind of Tone shall make the Pewter jar; a second Note will cause the China and the Glasses to sing; a third shall put your Seat in Motion, a fourth shall set your Teeth on Edge; and the like.

HENCE too it is, that some Persons are able to break a Drinking-glass merely by the Tone of their Voice when brought to a *Unison* with it. The Sound of the Glass, being struck, always gives its natural Note; which being encreased by Degrees, from a smaller to a larger Degree of Vibration, the Tremor at length becomes too great to be supported by so brittle a Substance.

FROM a Principle like this, with some Probability perhaps, we may, at least in Part, deduce the Cause of the customary lazy Action of Yawning, often appearing to be sympathetic. It must be allowed, that every Part of the Animal System is made up of Fibres, or little Strings: Of these the Muscles of the Flesh are composed; so are the Bones, Tendons and Nerves. all in a various Degree of Tension, according to their Texture, Office and Use. These are therefore ready to receive Impressions from the moving of their *Unison* Strings, and to repeat the Notes which they shall sound.

THE Person then that leads this delightful Concert, either having his Spirits wasted by a long Watching, or from some great Application, or

he may perhaps be enervated thro' a too long Indolence, whereby his Nerves and System of Fibres may be all relaxed (the animal Secretions not being duly made): These therefore want bracing up, and being all elastic Chords, by stretching they recur and naturally contract, after Extension, with greater Force and Vigour. Nature by this Means is a while refreshed, and when she flags again, is again stimulated to and relieved by a Repetition of the same Experiment. Now such of the Assistant-performers as happen to be in the same Circumstances, and have their Fibres lowered also down to the same Pitch, immediately take it, and like a Set of *Unison* Strings, conspire to give the same Note; this therefore often like a Contagion spreads, and goes round the Company.

AND from much the same Cause it doubtless is that good Musick has so great a Command over, and so visible an Effect on the Passions of Men. The fibrous System is always more unpliant in Age, and more pliant in Youth; some of those Fibres will correspond with, and be affected by Musick of one Sort; some by another. The Young therefore are usually delighted with Airs, which are gay, bounding and lively; the Middle-aged are more pleased with martial Musick, and the Din of War; and the Antient generally prefer the Solemnity of Church-musick to any other. Thus does our Taste of Things often vary with our Years; nor is our Opinion always within our Power. It will be prudent therefore, never, at least not too positively, to condemn, what

from the Changes in our natural Constitution and Frame, we may be in Danger one Day of falling into ourselves ; nor, on the other Hand, too eagerly to censure the Levity and little Extravagance of Taste in others, the Sense whereof we have either now out-lived, or from a different Organization of Body is what we could not possibly fall into.

WHERE a Multitude or the most of our Fibres are agreeably moved, by the excellent Performance of a fine musical Composition, we are apt to be transported. When mournful Sounds invade our Ears, we are moved to Pity ; sprightly Airs inspire Love ; martial Fury is to be raised by fitting Sounds, and proper Measures : And thus may the generality of human Passions be influenced by Musick ; as Mr. DRYDEN and Mr. POPE have finely described in their several Odes upon *St. Cecilia's Day*.

WHEREVER we meet with a Collection of harsh, discording, unharmonious Sounds, we are most sensibly tortured ; probably from the before-mentioned Cause : The Mind seems to be thereby unhinged, and great Violence is done to the whole Constitution. This made Lord VERULAM, who was a very good Judge of human Nature, think, that an Anti-musick might be contrived, of some Use in War, whereby Groans, Screams, and hideous Clamours, might be conveyed to the Ears of the Enemy, and Horror and dreadful Apprehensions to their Minds. But whether this might not

have

have equally a bad Effect on those who used it, is a Question; and perhaps one Reason why this Thought has been pursued no farther.

IT must, however, be confess'd, that the Shouts which our Countrymen frequently make, when they undertake any very hazardous Attempt in War, has its Use; chearing themselves, at the same time perhaps that it spreads Dismay among the Enemy; more especially since these act together, and in Concert execute the Commands they have received: While the adverse Party, being unapprehensive of what is meant or intended, are divided in their Sentiments, unprepared, and therefore less resolute in their Defence, than the other are in making the Attack.

THE Effect Musick has on Persons bit by the *Tarantula*, if true, is also a considerable Proof of the Power of Musick, in putting the Fibres of the Body in Motion. The *Tarantula* is a large Spider, said to be obnoxious only to the People of *Apulia*, a Part of *Calabria*, in the Southermost Part of *Italy*. The Patient after the Accident loses both Sense and Motion, and dies if destitute of Help. The most effectual Remedy is Musick. The Musician tries Variety of Airs, till he hits upon one that affects the Patient, who upon that begins to move by Degrees, and keeps Time with his Fingers, Arms and Legs, afterwards with his whole Body. He then raises himself up, begins to dance, increasing in Activity every Moment,

ment, till after five or six Hours smart Exercise in this Way, being much fatigued, he is put to Bed, to recover Strength. The next Day the same Air brings him out of Bed for a new Dance, and no other Persuasion whatever will incline him to stir. This Exercise being thus continued, the Distemper is abated in the space of four or five Days, the Effects of the Poison being then in some Measure carried off by Sweat, and the Patient begins to recover his Strength and Senses by Degrees.

I HAVE seen a Person that was born deaf, and probably so will always continue, when he held the End of a Violin between his Teeth, on which another played, rejoice very much, as being made that Way sensible of the Musick. This could only be communicated to his Perception by the Vibration of the solid Parts, the Bones of his Head, communicated by those of the Instrument.

AND this Experiment any one may make, by stopping his Ears with his Fingers so close, that he cannot hear an Instrument that shall be play'd on; let him then lean his Head, either against the Instrument itself, or apply it to the End of a long Stick that bears against the Instrument, and he will distinctly perceive every Note that is played.

THIS is one Way, and a very certain one it is, which the Mariners take to discover whereabout the Leak in a Ship is, when not easily to be found, *viz.* They take a Staff, and holding

ing one End of it tight to the Ear, they apply the other successively to the several Parts of its Sides, till they distinctly hear where it is the Water rushes in, tho' the Noise be too inconsiderable, and not possible to be found by the Ear alone. And every one knows how difficult 'twould be to remove all the Ballast and Stowage of this bulky Machine, in order to discover it any other way.

It is a common Experiment, for a Person listening at one End of an extended Cable, or a Stick of Timber of any Length, to hear a Scratch made with a Pencil, the Beating of a Watch, or a small Fillip with the Finger, at the other, purely by the Elasticity of the Parts of those Bodies. The Centinels of the advanced Guard, in Time of War, are ordered to lie on their Bellies, with their Ear to the Ground, that the earliest Notice of any Motion of the Enemy may so be had, and prevent a Surprise; the Sound being communicated a long Way by means of the Earth. And jealous Princes have sometimes had Pipes laid from the Council to the Cabinet, whereby they have become Masters of the Conferences there carried on, being conveyed by means of the elastic Fluid enclosed therein.

As the Effect of String-musick is produced by the Tremor or Vibrations of a sounding String, excited by a Blow, or some external Force applied; so is Wind-musick produced by those of the sounding Pipe, by means of the Influx of Air condensed. The Organ in particular has a very long Trough, air-tight,

with which the Pipes of the whole Instrument communicate, and into which all the Bellows are made to blow, in order to furnish a constant Supply of Wind. The Keys, lifting little Springs from time to time, let a Part of this Air out of the common Magazine, which immediately rushes into its peculiar Pipe, the nether End whereof is formed something like the Mouth-piece of a Flute; where meeting with a sharp Edge, exactly opposite to the Channel of Induction, the Stream of Air is thereby divided into two Parts, one whereof passes without the Pipe, and runs waste, the other pushes in with a Force sufficient to put the Parts of the elastic Matter, of which it is composed, into such a Tremor, as is proper to sound the intended Note, to which the Dimensions of the Pipe and other Circumstances also contribute. The Metal Pipes are cylindrical, the Wooden ones usually square.

It may be observed of the Flute, Hautboy, and such Instruments whereon the Notes of Musick are struck by the Help of Ventages or Holes made in the Trunk of the Tube, that they are not bored cylindrical, but conically; not only that the Tube may be kept of a due and manageable Length, but also to save a great Expence of Breath.

WAS the Tube of the same Bigness throughout, the Quantity of Wind requisite to sound the highest Note distinctly, would necessarily be attenuated in its Passage down it, gradually mingling

mingling with Air of the common Degree of Density found therein. This would require, let us suppose, the Aperture fit to sound the second Note to be placed an Inch below the first. The same Cause still increasing, let us suppose the third Note put at the Distance of two Inches, the fourth at three, the fifth at four, the sixth at five, the seventh at six, and the Octave at seven Inches. The Sum total of all these, with the Intervals proper to be left between the Extremities of the Flute and the Holes, would make the Tube of an inconvenient Length, and bring the Ventages not within the Reach of an ordinary Set of Fingers. It would also require an uncommon Stream of Air to replenish a Tube thus circumstanced; whereas, by the gradual Contraction of the Channel, as 'tis bored taper, the Wind will be rather condensed in its Passage, and to very good Purpose. To this Artifice the Workmen generally add another, which is, to make the Holes of a greater or less Diameter, according as the Note requires the Sound to be more or less sharp.

AND here we may not improperly mention the Organs of Speech, the Voice being modulated or governed by the Contraction, Extension and Management of the Muscles of the *Larinx*, which is made up of five Cartilages, different in Shape and Size, and distinct from those semicircular cartilaginous Rings which constitute the Windpipe; but are very nicely contrived and adjusted to one another for modulating

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dulating the Ingress and Egress of the Air in Respiration, Speaking, Singing, &c. The Muscles that move the Tongue, also contribute very much to the Production, Formation and Articulation of the Voice ; so does the apt Disposition and Organization of the other Parts of the Mouth, the Palate, Lips and Teeth. A just Arrangement of these greatly conduces to the Propriety and Harmony of Speech : And when those Parts are happily formed for the Purpose of Singing, the judicious Performer is now-a-days found to be in Possession of a very lucrative, as well as entertaining Qualification.

It is also from a Difference of the Organization in the Throat and Mouth of other Animals, that to express the same Passion of the Mind, one growls, another hisses, and another roars ; in the same Manner that equal Blasts from the same Lungs produces one Tone on the Trumpet, another on the French-horn, a third on the Bassoon, and the like.

On the SPEAKING-TRUMPET, and AURICULAR-TUBE.

THE Speaking-Trumpet was invented by Sir SAMUEL MORLAND, for the Benefit of making People hear at a Distance ; as at Sea, in a Siege, &c. It is a conical Tube, made of thin Brass, Tin, or other elastic Matter, from two to six Feet long.

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THE Reason why the Voice is magnified by this Machine is, because it is made of a Substance easily shaken, by the Vibrations whereof the circumjacent Air is put into greater Motion. These being successively propagated thro' the Tube, are continually reverberated or reflected from the Sides into its Axis, by that Means being prevented from spreading, till they get out of it. The gradual Increase of the Cavity of the Tube puts all Parts of the Metal into a proportionable Degree of Motion; so that what Tremors might be confined within the Compass of an Inch in Diameter at first, will be afterwards diffused so as to fill a Circle, perhaps twelve or fifteen Inches in Diameter, before it leaves the Instrument, which then generally becomes the Centre of Sound. It must, however, be observed, that the more sonorous and audible the Voice is made by this Means, the less articulate or distinct it is: Just as Light, to which Sound bears in many Things a pretty near Resemblance, the more it is diffused, the less will it distinguish the Objects whereon it falls; and the more it is condensed, the brighter and more distinct will the Objects it is thrown on always appear.

FOR a contrary Reason the Auricular Tube, the Figure of which is represented *Fig. 14. Plate 9.* assists such as are hard of Hearing, when not occasioned by the Humours becoming inspissated by Cold, &c. and the Obstructions consequent thereon. In which Case this Machine

chine can be of little Service ; washing out the Wax does much better : But when the Organ itself is by Age enfeebled and decayed, that is, when the acoustic as well as other Nerves have lost their Delicacy, this Tube may be of real Use and Service, in rendering Sounds more distinct and audible.

THIS Machine then seems to be just the Reverse of the Stentorophonic Tube, or the Speaking-trumpet just mentioned : As the Use of that is to dissipate, this is intended to collect the Rays of Sound. With regard to the Structure of it, the Base is best made in Form of the parabolic Curve, finishing at Top with a small bent Tube, that it may more conveniently be applied to the Ear. It does thus in some Measure resemble the auditory Duct, or the inner Ear itself, which is also something conical, having the Base outward, and the *Apex* next the Head ; that so a larger Quantity of the moved Air may be collected, received, and thereby transmitted to the Point of the auditory Nerve, which must be shaken to produce Hearing and give this kind of Perception. So that this Contrivance is in Effect no more than the Base of the Ear enlarged, and therefore capable of intercepting more of the Rays of Sound than the Ear alone ; and that in Proportion to its Base. And these being gradually contracted into the smaller End, are thence thrown upon the *Tympanum*, and affect the inner Ear according to the Force and Quantity of the Impression received.

THE Smoothness of these Machines is no small Advantage to the Conveyance of Sounds thro' them; for by Experiment we know, that these always glide with most Ease, and move the farthest, over smooth Surfaces, where there is nothing to obstruct and divert their Progress, or to occasion a Rebound.

On Places of HEARING.

IT may seem incredible, that the Voice of a Man might be distinctly heard at the Distance of ten or twelve Miles: But a Gentleman of great Veracity, who had lived some Years at *Gibraltar*, affirms to me, that he has at *Old Gibraltar* heard the Watch-word of the Night, *viz. All's well*, given by the Centinels to the Patrole, passing along the Ramparts of *New Gibraltar*, in a still serene Night, when the Water was perfectly smooth, and that, he thinks, as plain and distinctly as those who walked the Round, or himself (had he been upon the Rampart) could have done. The Bay between the two Places he judges to be about three *Spanish* Leagues over. This is a sufficient Proof of the Service it is to Places of Hearing, that their Surfaces should be as smooth as possible. Carpets, Hangings, and the like, are great Impediments to Hearing. Such Furniture having nothing elastic in it, the Voice is damped and deadened thereby. Snow lying on the Ground will do the same thing, and even alter the Tone of Bells seemingly very much.

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FOR this Reason the Surfaces of Whispering-places are commonly made very smooth. They are besides this, commonly disposed and built in a circular, or at least a curvilinear Form, capable of catching and transmitting all the Reflexions of Sound that come within their Compass. That of the greatest Note in *London*, is in the grand Gallery of *St. Paul's Cupola*. Just above the Gallery is a strong smooth blank Wall painted, being the Basis of the Dome. It is circular, and being the Zone of an Ellipse, it is not quite so wide at Top as at Bottom. Let a Person here speak with his Cheek to the Wall, in Whisper, he will be audibly heard quite cross the Gallery; the Reason of which comes next under Consideration.

LET *ABC*, &c. *Fig. 15. Plate 9.* represent the Line or Part of the blank Wall, against which the Speaker whispers. The Air put into Motion thereby, impinging first at *A*, according to the Angle in which he directs his Voice towards the Wall, will be thence reflected to *B*, thence to *C*, to *D*, to *E*, and so on to *F* and *G*, where the Reflexions, brought by the collateral and contiguous Lines, will also nearly meet, and by their Union, there cause a much stronger Sound than in any other Part of the Circle whatsoever; much greater than at *A*, the Point from whence the Sound originally came. It will be very well heard at *G*, if there happens to be a Pier, or somewhat projecting,

jecting, to stop and reflect it thence at once : But if there be no such thing, nor any Ear to receive it applied, it will probably proceed quite round the Dome, and come again to the Speaker himself, tho' much diminished, at *A*, on account of the more frequent Reflexions it must have suffered in passing over twice the Space. Nor is this the only Cause of this Phænomenon ; for the Air thus agitated by the Voice, and passing round the Zone, as before-mentioned, is very much augmented by something of a like Course it also takes, from the Lips of the Speaker, quite cross the upper Part of the Dome ; which being elliptical, is from its Form and Structure, of good Advantage to the easy Reflexion of the bounding Voice, in its Passage from one Side of the Figure to the other ; the Rays of which there concentrating as it were, and meeting, make their general Effort diametrically on the opposite Side ; especially if they happen to come thither all at the same Time.

AN Ear placed at the *Vertex* or Top of a Dome, or indeed any other vaulted or arched Place, would find any Sound, made within reach, very much magnified, on account of the many Reflexions made from Side to Side thro' every Part of the Hemisphere : But it will be found also confused and very indistinct, not being placed in or near the focal Point of the Figure : And hence proceeds the Bomb that generally attends Voices uttered, and Noises made in cavernous and vaulted Places : For
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which Reason also flat Sound-boards to Pulpits, and flat Ceilings to Rooms are much fitter to spread the Voice and keep it articulate, than those of any other Form.

IN Auditories, such as Churches, Theatres, Courts of Judicature, &c. where the Hearing distinctly and well may be of Use, the Form of the Building should be a little considered. We know, that if a lighted Candle be placed in one of the *Foci*, or the Centres, from whence an Ellipse is described, as at *A*, *Fig. 16. Plate 9.* the Rays of Light, supposing the Hoop to be made of bright Tin-plate, or other polished Matter, will be generally reflected into the other of them, as to *B*, which will then be the Point most enlightened. And there being a great Similarity between the Progression of Light, and that of Sounds, as was before hinted, it will thence follow, that whatever Sounds, proceeding from one of these Points, shall be caught by the Walls of an Edifice of this Figure, will be reflected thence, with great Advantage, toward and indeed into the other, following the Direction of the Lines *AC, CB; AD, DB; AE, EB; AF, FB;* and *vice versa*. If one of these central Points be appointed for the Evidence, and the Criminal, the Judge, and Jury, might be very well posted in the other, as it is the most commodious Point for Hearing that can be contrived.

IN general it may be observed, that all the Auditors will by the Reflexion of the Voice from
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some one or more Parts of a Room that has its Area of the above-mentioned Form, hear the Speaker much better in every Part, than in one that happens to be incumbered, or of a less advantageous Figure for the Purpose. The good Effect of such a Disposition is, by Experience, well known to the Inhabitants of St. *Anne's, Westminster*; for the Reader is certainly much better heard, in all the remoter Parts of the Church, from the Communion-table, placed in an Alcove of that Figure, than from the Reading-desk, tho' it be a great deal nearer. The Theatre in *Oxford*, wherein this Matter was very rightly considered by its great Architect Sir CHRISTOPHER WREN, is, regarding its Dimensions, an excellent Room for Hearing, of which the Ceiling is flat, smooth, and painted: Whereas in the Amphitheatre of *Barber's and Surgeon's-Hall* near *Cripplegate, London*, the Speaker is not so distinctly heard, tho' the Room is many Degrees less, having the Ceiling eaved.

On the ECHO.

THE Antients, being wholly unacquainted with the Cause of the Echo, ascribed it to several Causes sufficiently whimsical. The Poets, who were not the worst of their Philosophers, imagined it to be a Person of that Name metamorphosed, and that she affected to take up her Abode in particular Places; for

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they found by Experience, that she was not to be met with in all.

WE are very well satisfied, that the Echo is produced by the Reverberation or Reflexion of Sound from certain fixed Objects to the Ear, placed in a proper Situation to receive the Impressions returned thither by the Recoil of the Air. From this Cause the Sound is always weaker in the Return, than in its direct Progress forward.

THERE are several Places fit for the Echo; Experience easily points them out to us. For Instance: *Fig. 17. Plate 9.* *F* is an old Building, having a blank Wall. *C* is the Stand of the Speaker, about two hundred Paces distant. The Ground from *C* to *F* lies on a Declivity. Here placing yourself directly fronting the Wall, and pronouncing any Number of Letters currently and clearly, the last eight of them will be perhaps distinctly repeated, and with the self-same Intervals wherewith they were uttered. If you pronounce the same at *D*, you hear perhaps only the three or four last; and if at *E*, you perceive no Repetition at all. The Reason is, because at *E* the Stroke arising from the Vibration of the Air is reflected to the Ear the very Moment it is made; whereas at a proper Distance, the Sound reverberated from *F*, at fitting Intervals returns first one Syllable, and then another, till eight, and often more, according to the Situation and Distance of the Place, as was said, are distinctly and successively heard.

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THE Distance of the Object returning the Echo, may be pretty well known by the Number of Syllables which it repeats. No one Syllable or single Note will be returned clearly under the Distance of twenty-four Paces or an hundred and twenty Feet, and so on in a direct Proportion : The Echo then returning eight Syllables, must come from an Object distant at least an hundred and ninety-two of the former, and nine hundred and sixty of the latter.

DR. PLOT, in his *Natural History of Oxfordshire*, informs us of an Echo in *Woodstock Park*, which in the Day, when little Wind was stirring, returned in his Time seventeen distinct Syllables, and in the Night, twenty. The probable Reason why it repeated more Syllables by Night, than it did by Day, is, because the Air being then colder, was consequently denser, whence the Return of the Vibrations became slower, which gave Time for the audible Repetition of more Syllables.

THE Cause why some Echo's return more, and some fewer Syllables, lies, without all Doubt, in the different Distances of the Objects returning the Voice to the Ear. In a Wood of lofty Trees, the barking of a single Dog may be so soon and so often repeated, that it shall resemble the Opening of a whole Pack ; and for a like Reason the Fret-work pendent from the Roof of *Gothic* Choirs, at *King's-College* Chapel in *Cambridge*, for

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Instance, and many other Places, procures a considerable Lengthening of the Sounds, from their frequent Repetition by the Means before-said, which is esteemed an Advantage to Church-musick. These are called Tautological Echo's; some of which will return a Clap with the Hands, or a Stamp with the Foot, eight, nine or ten times distinctly; the Noise dying as it were away, and melting by Degrees, becomes constantly weaker and weaker. There are also, as the Lord VERULAM observes, Echo's upon Echo's, which he calls Back-echo's: These may promote the harmonious Dying away of the Notes in the forementioned Places, but are otherwise inconsiderable.

IT may be observed, that all Echo's have some one Place, whither they may be returned, so as to be heard by a Man's self more strongly and distinctly than any other; and that is always that lying at Right-angles with the returning Object: For if a Man stands obliquely to it, the Voice will be better returned, and more distinctly heard by another Person at some other Place. The Angle of Incidence is always equal to the Angle of Reflexion; the Note or Sound thrown directly on any Object, will therefore be returned nearly in the same Line: Whereas that which is thrown thereon obliquely, will be thence reflected in the same Manner, and will reach another Place with greater Advantage. For Instance: Let the Speaker at C, directly

front

front the Building at *F*, *Fig. 17. Plate 9.* he will plainly hear his own Words, by reflex Sound. Let him remove to *G*, the Echo will be most audible at *H*; and if the Voice be uttered at *I*, the Reflexion will best be made at *K*.

THIS being all material, that occurs at present, on the Subject of the Air, and its Dependencies, let us conclude this Treatise with some Account of the Tides.

On the T I D E S.

THE Tides could no way be accounted for, till Sir ISAAC NEWTON discovered the Principle and Properties of universal Gravitation; that is, the Force whereby not only every Particle of Matter in each Planet tends to the Centre of that Planet, but also that whereby the Planets reciprocally tend to one another, and the whole Chorus of them in general to the Sun, being by far the greatest Body: As also that the Force of the Attraction exerted by those Bodies at different Distances, is reciprocally as the Squares of those Distances.

IT is one Consequence of these Principles, that the Earth, Sea, and the celestial Bodies, acquired at first, and still preserve, their spherical Figure: And tho' the Tenacity and Firmness of the solid Parts may in some Places

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support the Inequalities of the Land above the ordinary Level; yet do the Fluids pressing equally, and easily yielding, soon resume their Equilibrium, whenever it is disturbed, and more exactly maintain the Figure of the Globe.

ANOTHER Consequence of them is, that tho' heavy Bodies on the Surface do gravitate and tend toward the respective Centres of the Sun, Moon and Planets, yet is the Force exerted by the gravitating Body, in its Descent towards the Centre, in all Places not alike; but is still less and less, as the Distances from that Centre increase: That is, both the Weight of Bodies and the Force of their Fall is lessened in Parts more removed from the Centre, in the Proportion of the Squares of the Distance. For Example: A hundred Weight on the Surface of the Earth being removed one Semidiameter from the Centre more, or raised to the Height of about four thousand Miles above the Earth, would weigh but a Quarter of a Hundred, and removed still four thousand Miles farther, no more than a Quarter of that, or seven Pounds; and consequently, the Body that should weigh three thousand six hundred Pounds in the Centre of the Earth, at the Distance of the Moon would weigh no more than a Pound, by the same Rule. And in the same Proportion does the Velocities of the Fall of Bodies decrease. For as on the Surface of the Earth, all things not impeded by the Medium, fall about sixteen Feet in a Second; at one Semidiameter above it, would fall but four Feet in the

the same Time; at four Semidiameters from the Centre, no more than one Foot in a Second; and at the Distance of the Moon, 'twill fall no farther in a Minute than it does near the Earth's Surface in one Second of Time.

FROM these Principles, not only the Theory of the several Appearances in the System of the Moon and Planets is discovered, and accounted for, but also the general Cause of the Tides may thence be deduced, and sufficiently explained.

THE Moon revolves, as it were, round the Earth, to which it is a Satellite or an Attendant Planet, in twenty-seven Days, seven Hours, and forty-three Minutes, at the Distance of about two hundred and forty thousand Miles from its Centre, having but about a fortieth Part of the Matter contained in the Earth. The Earth, at the Distance of about eighty-one Millions of Miles, revolves round the Sun in a syderial Year, *viz.* in three hundred sixty-five Days, six Hours, and about three Minutes and a quarter. His Quantity of Matter is one hundred sixty-nine thousand two hundred and eighty-two times that of the Earth, according to Sir ISAAC NEWTON'S last Calculation.

THE Earth then attracts the Moon in a superior Degree, and confines it from flying off in a Tangent Line to its Orbit, which would happen, were it not for this Attraction. The Moon, in its turn, re-attracts the Earth to

a certain Degree; the solid Parts whereof being rigid, seem not to be affected by it: But the Fluids yielding thereto, rise, swell, and thereby seem to confess its Power. The Sun, in like manner, attracts the Earth, so as to preserve and keep it in its annual Orbit; in some sort also it affects her Fluids; but, by reason of his very great Distance, seemingly in a much less Degree than does the Attraction of the Moon.

It being demonstrable then, that the Earth is within the Sphere of the Attractions of both Sun and Moon; it follows, that the Equality of the Pressure of the Gravity of Matter, or its general Tendency toward the Centre of the Earth, will be thereby occasionally disturbed. Was the Earth intirely free from the Actions of the Sun and Moon, the Ocean, being equally attracted on all Sides by the Force of Gravity, would continue in a perfect Stagnation, and neither ebb or flow: But as the Case is otherwise, it must needs rise higher in those Places, where the Actions of the Sun or Moon shall occasionally diminish its Gravity.

THE Action of these upon the whole Mass of the solid and coherent Earth, is the same as if all its Matter were accumulated and contracted, and the whole Weight of it were brought into and deposited in its Centre. For the Parts about *Z* are just so much more attracted by the Moon at *L*, *Fig. 18. Plate 9.* by how much the Parts about *N* are attracted less than

is the Centre T , and *vice versa*. And since one compensates for the other, it follows, that the whole Body of the Earth at $ZOHN$ is equally attracted by the Moon at L , as if all its Parts were reduced into and fixed in the Centre T . We may therefore speak of the solid Parts of the Earth, exclusive of the Water surrounding it, as of that Point.

THIS premised, let us next consider the Globe of the Earth as covered with a deep Sea: It will then follow, that by the yielding hereof, the Earth will put on the Figure of a Spheroid, whose longest Diameter, if produced, would pass thro' the Moon: That is, wherever the Moon is vertical, she will not only raise Tides immediately under her, in the Zenith at Z ; but also, at the same time, in the Nadir, or the opposite Point of the Earth at N . She raises the Water in the former, because the Fluid there is near four thousand Miles nearer to her attractive Power, than is the Centre of the Earth at T ; it therefore gravitates less, and becomes lighter, than that in the Parts about H and O , lying in the same Line with T , and, in order to preserve the general Equilibrium, presses of course toward Z , and causes an Accumulation, or Swell of the Fluid there.

THIS then is the Cause of the Tides in the Zenith. But to account for those in the Nadir, we must observe, That as the Water in Z is attracted more by the Moon at L , than is
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the Earth at T ; so is the Earth at T thereby more attracted than will the Water at N , lying near four thousand Miles still farther distant from such her attractive Power. The Water therefore at N tending less toward the Moon at L , than the Earth at T , will be less attracted by the Difference of Gravitation toward the Moon severally in T and N ; which, as has been said, is according to the Squares of their respective Distances reciprocally.

THIS rightly understood, it will plainly follow, That the Ocean must on these Occasions necessarily put on a spheroidic Figure, whose longest Diameter will be where the Moon is vertical, and shortest where she appears in the Horizon: And that the Moon, apparently shifting her Position, as she seems to turn round the Earth once a Day, from East to West, (produced however by the Rotation of the Earth, from West to East, upon her own Axis) thereby occasions the Floods and Ebbs, observable every twenty-four Hours four fifths, which happens to make the mean Length of a lunar Day.

IT may not be amiss to endeavour to explain this Difference of the Moon's Attraction between the Parts in the Zenith, Centre, and Nadir of the Earth, by a familiar Example. Let us suppose, a four-oar'd Boat a-head, a Wherry with a pair of Oars in the middle, and a third Vessel with a pair of Sculls behind, all of the same Bulk and Weight, and floating at
equal

equal Distances from each other, down the Stream, without Rowing : Being all impelled with the same Force, or carried by the same Stream, they will all move equally, and keep, in general, the same Distances they had when they first set forward. In this Circumstance they will represent the three forementioned Parts of the Earth moving regularly in the Expanse, and barely proceeding in her Orbit round the Sun. Let then the Rowers, according to their several Power and Force, begin at once to work, the four-oar'd Boat will soon gain Ground upon the other two, and the two-oar'd Boat will leave the Sculler behind, in Proportion to the several Forces wherewith they shall be wrought. The advancing of the foremost Boat will easily denote the ready Rising of the Water toward the Moon, when in the Meridian ; the coming forward of the central Parts of the Earth will be signified by the getting on of the middle Boat ; and the Swelling of the Water in the opposite Point, will be represented by the lying behind of the Sculler.

OR again ; Suppose a String fastned to a concave Sphere, say of Wire, which has a Bullet in it loose ; as soon as the Sphere shall be whirl'd about, at the End of the String, the Bullet will recede from it as far as may be ; and it will be found always diametrically opposite to the String, and endeavouring to fly off, will, by its centrifugal Force, draw the Sphere, not
being

being perfectly rigid, into the Form of a Spheroid.

OR once more; Suppose the String fastned to the Bullet within the Sphere, now left at Liberty, and being together whirl'd about as before, the Bullet will remain in the Place where it is confined by the String; but the Sphere not being perfectly rigid, will, from its own Weight, be drawn out, as before, into a Spheroid.

To apply this; Imagine the great Ocean, which we before supposed to cover the Earth, to be analogous to the Sphere; the Earth to the Bullet, and the Gravity between the Moon, Earth and Water, to the String, whereby they are retained in their Orbit, and the Gravity or Attraction between the Earth and Water, to the Rigidity of the Sphere: Suppose then the Water to gravitate towards the Moon, and the Earth not; of consequence the whole Mass of Waters will get into the Zenith, and the Earth will seem rather to endeavour to recede from the Water, as the Bullet inclines to do. But the natural Attraction between the Water and Earth answering, as was said, to the Rigidity of the Sphere, will not suffer it wholly to fly off, whence the Earth will remain in the Point the most distant from the Moon, that is, in the Nadir: And this is fitly represented by the String's being fastned to the Sphere.

AGAIN; Suppose the Earth to gravitate toward the Moon, and the Waters not, the Earth will

will then be in the Zenith, and the Waters will take their place in the Nadir; which again would quit the Earth, but for the Attraction between the Earth and Waters: And this is correspondent to the whirled Bullet's being fastned to the String, leaving the Sphere at Liberty.

LASTLY; Suppose both the Earth and Water to gravitate towards the Moon, as they really do, 'twill follow, that the Parts of the Water nearer the Moon than the Earth, will be more attracted thereby, and rise into the Zenith: Whereas the Parts of Water which are farther from the Moon than the Earth, will be less attracted on the whole, and so flow into the Nadir. By which means Tides will be raised both in the Zenith and the Nadir, at the same Time: And this may suffice to give an Idea of the general Cause of the Tides. Let us now consider their Phenomena in particular Places.

I. THE Tides flow according to the lunar and not the solar Day, tho' the Action of the Sun on the whole Body of the Earth, be to that of the Moon as three hundred to one hundred sixty-nine; the Quantity of his Matter before-mention'd, more than compensating for the Greatness of his Distance. In considering of this Affair, however, we are to distinguish between the absolute and relative Attraction of these two Luminaries. Absolute Attraction is that which acts upon all Parts of the Body with a Force nearly equal; but relative Attraction is that which

which is exerted upon some Parts of a Body more intensely than others. Hence 'twill appear, that the Tides must be the Consequence of a relative or partial Attraction ; and the relative Attraction of the Moon being greater than that of the Sun in particular Places, thence it is that the Tides will generally follow the Moon, and not the Sun, as by Experience we see they do. Now the relative Attraction of the Moon exceeds that of the Sun, because a Semidiameter of the Earth bears a very sensible Proportion to the Distance of the Moon, it being about one fixtieth Part thereof ; but a much less to that of the Sun, of which it is scarce the twenty thousand two hundred and fiftieth Part.

2. THE Tides happening about fifty Minutes later each Day, is the Consequence of their following the lunar Day. Thus, if 'tis High-water to Day at twelve o'Clock, it will be High-water to-morrow at twelve Hours fifty Minutes, that is, twenty-four Hours fifty Minutes after Twelve to day. The lunar Day is so much longer than the solar ; because while the Earth turns from West to East, toward and from the Sun, in twenty-four Hours (at the same time getting forward, at a certain Rate, in her own Orbit) the Moon also proceeds from West to East, one twenty-seventh Part of her Orbit, in some measure keeping Pace, tho' not an equal Pace, with the Earth.

3. THE Tides being greatest, *ceteris paribus*, when these Luminaries are in *Perigæo*, or at

at their least Distances from the Earth, is consonant to the Laws of Gravitation, which, as has been said, are more or less powerfully exerted, *viz.* in Proportion to the Squares of the Distances of the Bodies under Consideration reciprocally.

4. THE Tides are, *cæteris paribus*, greatest when the Sun and Moon are either in Conjunction at the New Moon, or in Opposition at the Full. In the first Case, the Moon is one Semidiameter of her Orbit nearer the Sun than is the Earth; in the second, she is a Semidiameter of her Orbit more distant than the Earth from the Sun. In either of these Cases, the Actions of both Luminaries will concur to raise the Tides. In Conjunction they both conspire to elevate the Waters in the Zenith, and by consequence, at the same time, in the Nadir: In Opposition, while one makes High-water in the Zenith and Nadir, the other endeavours to do the same in the Nadir and Zenith, as already explained: And this is the natural Cause of the *Spring-tides* produced at those Times. In the Quadrature or Quarters, the Actions of the Sun and Moon interfere, and in part obstruct each other; *viz.* the Water raised by the Sun is depressed by the Moon, and the contrary: Hence it is, that the Tides are less at those Times, and are distinguished by the Denomination of *Neap-tides*.

5. IN Places not under the Equator, the Tides are not equal, but are alternately greater
and

and less. The Reason of which will be better understood by regarding *Fig. 19. Plate 9.* Let *APEP* be the Body of the Earth covered with deep Water, *C* the Centre, *P P* the Poles, *E A* the Equator, *F f*, *D d*, Parallels of Latitude, *H b* the Axis of the watery Spheroid, *L* the Moon's Place, *K k* the Circle wherein the Moon then appears horizontal to one rising to the other setting; the Lines *B F*, *B D*, *B f*, *B d*, shall denote the Height of the Sea at the Places *F f*, *D d*, in each of which it is High-water, but highest at *F*, because the Moon is nearest its Zenith; and so at *D*, because that is the *Antipodes* of *F*, or the Point diametrically opposite, considering the daily Rotation of the Earth is upon the Axis *P P*; by which Means too the Point *F* will in twelve Hours Time be transferred to *f*, and the Point *D* to *d*; now whereas the Lines *B f*, *B d*, are evidently shorter than the Lines *B F*, *B D* (that is, the Water is lower in those Places) it follows, that the Points *F* and *d*, must, in the Space of twelve Hours, pass thro' low and high Water alternately, whilst the equatorial Parts *A* and *E* pass thro' Tides equally elevated, since *C A* and *C E* always continue equal.

6. THE Tides, *ceteris paribus*, are observed to be greater when the Luminaries are in or near the Equator, than when at their greatest Declination from it. This arises from the two opposite Protuberances, which at that Time are in the Equator, and which of consequence describe there the greatest Circle of the Earth; whence

whence by the diurnal Rotation, they will move swifter, describing the greatest Circle of the Earth, in the same Time that they used to describe the lesser ones, parallel to it; and consequently, being thrown upon the Shores with greater Force, they rise higher there. For it is plain, that if the Moon were fixed in the Pole, that the watery Spheroid would tend thither, producing always high Water there, and low Water every where under the Equinoctial; and therefore the nearer the Moon approaches the Poles, the less is the circumvoluntary Agitation of the Ocean in particular Latitudes, which of consequence must be the greatest when she is in the Equinoctial, or the farthest removed from the Poles.

7. THE Time of high Water happens not precisely at the Time of the Moon's Appulse to the Meridian; but about three Hours afterwards, or when she is toward South-west. This is, because the Moon acts with some Force, after she is past the Meridian, thereby adding to that Libration, which she had put the Waters into, during her coming to, and whilst she was in the Meridian: Not unlike the Time of the greatest Heat in Summer happening about two or three Hours after Noon; or just as a smaller Force apply'd to a rising Ball, will raise it still considerably higher.

8. THE Tides are observed to succeed each other quicker in the Transits or Passing of the Luminaries from their Conjunction and Opposition,

position, commonly called their Syzygies to their Quadratures, than from the Quadratures to the Syzygies. In the latter Case, the Tides grow continually larger, and the larger they are, the longer they are in rising and falling; as the more Length a Pendulum has, the longer it is in making its Vibrations: and of consequence they ought to succeed quicker in the Transit from the Syzygies to the Quadratures; because, by a Parity of Reason, they then grow less and less.

9. THE Tides often fall out greater in *February* and *October*, than at other Times. The Reason of this, not happening precisely at the two Equinoxes, as they ought to do, but something before the vernal, and after the autumnal Equinox, is, because the Sun (as the Planets move round him in elliptic Orbits) is nearest the Earth in the Winter Months (for the Earth's Motion is then certainly swiftest, as appears by the Winter's being always eight Days shorter than the Summer) consequently the Sun comes then to have a greater Influence in producing the Tides, than usual, and causes the Alterations spoken of. But it does not happen every Year so; because some Variations may arise from the Declination or Situation of the Moon's Orbit at that Time, and the Distance of the Syzygies from the Equinox.

10. The Morning and Evening Tides are remarked to be often different in Height. This is owing to the Moon's being nearer or more distant

distant from the Zenith or the Nadir. While the Sun is in the northern Signs, the greater of the two diurnal Tides, in our Climates, is that arising from the Moon's being above the Horizon; when the Sun is in the southern Signs, the greater is that arising from the Moon's being below the Horizon; that is, according as their Influences act together, or oppose each other.

AND such probably would the Tides regularly be, if the whole Earth were covered with Water, very deep: But by reason of the Shoalness of some Places, and the Narrowness of the Streights in others, thro' which the Tides are to pass, there arises great Diversity in the Effects, which are not to be accounted for without a perfect Knowledge of all the Circumstances of the Situation of the Land, the Breadth and Depth of the Channels, &c. For a slow and almost imperceptible Motion of the whole Body of Water, where, for Example, it is two Miles deep, might suffice to raise its Surface ten or twelve Feet in a Tide's time very well; whereas, was the same Quantity of Water to be conveyed thro' a Channel but forty Fathom deep, it would run like a Sluice to effect it, as it does in the narrow Parts of the *British* Channel on some Occasions. This also may be one Reason why high Water in many Places happens not nearer the Time of the Moon's being in the Meridian.

IT may here be remarked, that the Motions hitherto mentioned must be somewhat altered

by the Libration of the Water, which, in forming the Tides, acts something like the Vibrations of a Pendulum, whereby the Flux and Reflux of the Sea would for some time continue, tho' the Luminaries should be at once annihilated, and their Actions intirely cease: This Conservation of the impressed Motion diminishes the Differences that would otherwise be between two consequent Tides; and is the Reason why the highest Spring-tides are not precisely on the new and full Moons, or the Neap-tides on the Quarters, but generally about the third Tide after them, and sometimes later.

To answer all the Phænomena of the Flux and Reflux of the Water in particular Places, would be endless; but all things duly considered, they are fully soluble by the Doctrines and Theory before laid down. As the most notable Instance of this kind, let us take notice of the Tide that comes into the Port of *Tunquin* in *China*. Here it ebbs and flows but once in twenty-four Hours; and twice in every Month, that is, When the Moon is near the Equinoctial, there is no Tide at all, but the Water is entirely stagnant: With the Moon's Declination, however, there begins a Tide, which is always greatest when she is in the tropical Signs; with this Difference only, that when she is northward of the Equator, it flows when she is above the Horizon, and ebbs when she is below it, so as to make high Water at Moon-setting, and low Water at Moon-rising: Whereas, on the contrary, the Moon's being to the southward of the Line, makes it high Water

at

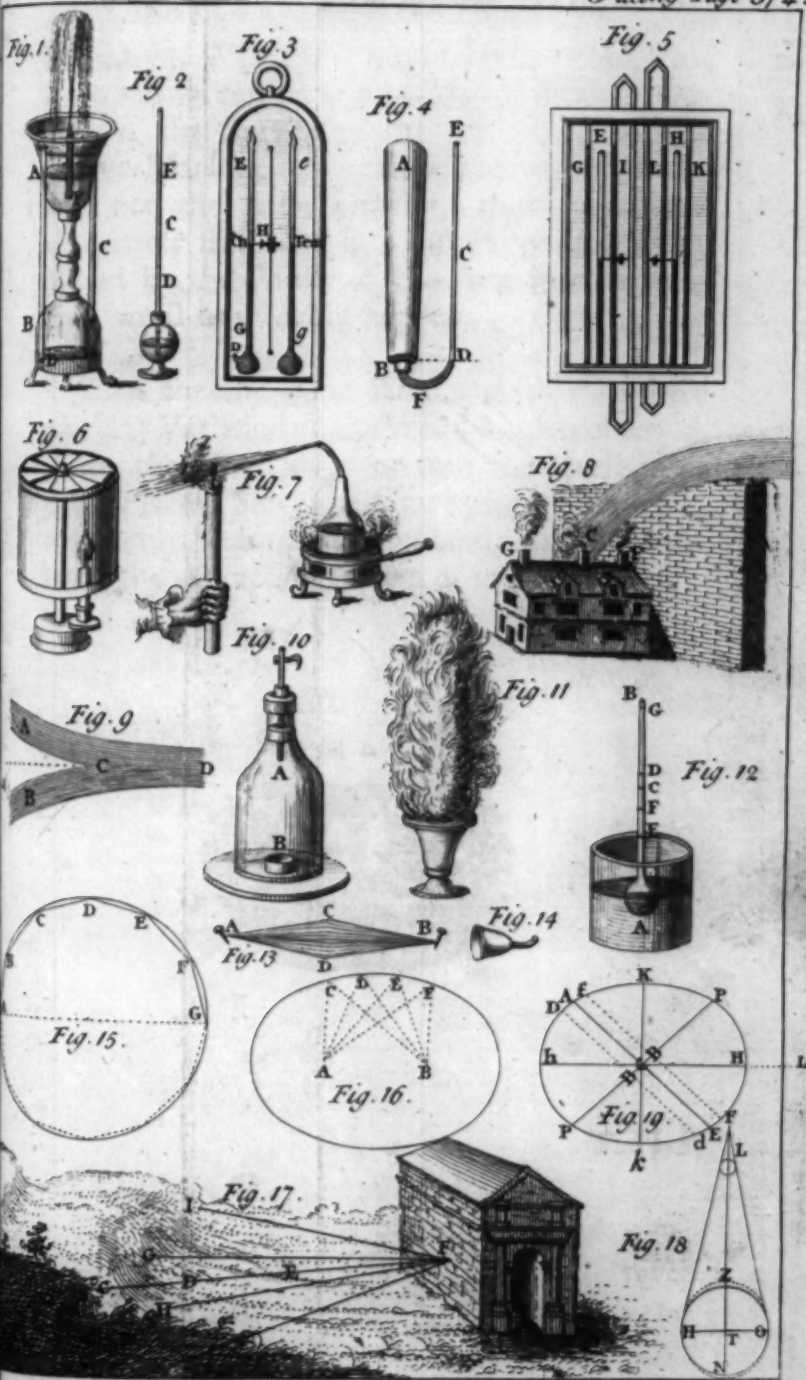
at her Rising, and low Water at her Setting ; and it ebbs all the time she is above the Horizon.

THE Cause of this odd Appearance is proposed by Sir ISAAC NEWTON, in his *Principia*, as arising from the Concurrence of two Tides ; the one propagated in six Hours, out of the great *South-Sea*, along the Coast of *China* ; the other out of the *Indian Sea*, from between the Islands, in twelve Hours, along the Coast of *Malacca* and *Camboya*. One of these Tides being produced in North Latitude is, as has been said, greater when the Moon, being to the North of the Equator, is above the Earth, and less when she is beneath it. The other of them, promoted from the *Indian Ocean*, being raised in South Latitude, is greater when the Moon, declining to the South, is above the Earth, and less when she is under it. So that of these Tides, alternately greater and less, there comes always successively two of the greater, and two of the less every Day : and the high Water falls always between the Arrival of the two greater Floods, and the low Water between the Arrival of the two lesser. The Moon coming to the Equinoctial, makes the alternate Floods equal, the Tides then cease, and the Water seems to stagnate : But she being passed the Equator, those Floods, which in the former Order were the least, now become the greatest ; the Times of high and low Water are then inverted, and the whole Appearance of these strange Tides is naturally and with Ease to be solved from the Theory thus laid down.

THE Seas nearly environed with Land, such as the *Mediterranean*, *Red-Sea* and *Baltick*, have no apparent Tides; because the Streights whereby they communicate with the Ocean, are Inlets so small, and the Seas themselves such large Bodies of Water, that Water sufficient cannot, in the Compass of a few Hours, be received into, or sent out of them, to cause their Waters to rise or sink considerably on so large a Surface.

THE *Caspian* Sea is no more than a very large Lake, having no Communication with the Ocean at all. This, as well as all other Lakes, is too small to be sensibly affected by the Attraction of the Moon, even where she is vertical: For she needs must attract all Parts of these Waters alike, rendering them in every Place equally light; so that no Part of them can be raised perceptibly higher than another. Or, in other Words, they are generally so small, as not to be capable of any relative Attraction from the Moon.

IT may here be remarked, that the Swell of the superior Air, or those aerial Tides before hinted at, probably occasioned by the Moon's Attraction when she happens to be vertical, or even near the Meridian of any Place, as well as are constantly those of the Waters, where no evident Cause of Obstruction appears, is not however observed to produce any perceivable Variations on the Height of the barometric Mercury;



Mercury : Whereas it might be expected, that from the Accession of new Matter on those Occasions, the Gravity of the Air might by that curious Machine appear to be increased ; which, was not the Air's Gravity, thus augmented adequately still, and in a just Proportion diminished by the Power of the Attraction before-said, must unavoidably happen.

AND for the same Reason neither is there ever any Variation on the Weather-glass observ'd, when the Moon is in or near the Horizon of those Places : Since the Gravity in one Case will reasonably be admitted constantly to counterbalance the Attraction spoken of in the other.





THE GLOSSARY;

O R, A

Short EXPLANATION of such uncommon Words as could not without Affectation be omitted in this Treatise.

A



*Bdome*n, the lower Belly.

Absorb, to drink in ; to swallow.

Acid, sour ; Matter fermenting with an *Alkali*.

Accelerated, hastened, or hurried forward.

Accumulate, to heap up.

Acoustic, see *Auditory*.

Adequate, equal thereto.

Adhesion, the sticking of Parts together.

Aether, an imaginary Fluid, fine and subtle.

Aliments, Food to nourish.

Alkali, fixed Salt of Substances fermenting with Acids.

Alternate, first this, then that ; by turns.

Ambient, surrounding.

Analogy, Proportion, Comparison.

Analogous, bearing Proportion, &c.

Aorta, the great Artery leading from the Heart.

Apex, the Point or Summit of a Cone or Pyramid.

Apparatus, Instruments for Operation or Experiment.

Appendix, Supplement ; something added.

Appulse, the Arrival of a Planet at a certain Point.

Articulate, to joint ; or under distinct.

Affimilate, to make like.

Atmosphere, the Fluid Mass of Air, &c. surrounding the Earth, to about sixty Miles high.

Attenuate, to thin, or make a thing weaker.

Attraction, a drawing towards ; producing a Tendency.

Aura,

A GLOSSARY.

Aura, a finer kind of Air.

Auditory, belonging to Hearing.

Auricular, belonging to, or received by the Ear.

Axis, an Axle on which any thing turns.

B

Bronchia, the Branchings of the Wind-pipe continued throughout the Lungs.

C

Capillary, small as an Hair.

Cæteris paribus, in other Circumstances the same.

Centrifugal, a Direction given a Body different from that inclining to the Centre.

Centripetal, tending toward the Centre.

Chalybiæ, belonging to Iron and Steel.

Chasm, a Gap, or Opening in the Earth.

Chimæra, a groundless Fancy.

Circulate, to come round.

Circumvoluntary, revolving.

Coalesce, to grow together, or unite.

Cohesion, a clinging, or sticking together.

Collateral, lying side by side.

Collision, a Striking, or Dashing against.

Compages, a Collection.

Complanation, a Flattening.

Compress, to squeeze close together.

Concave, spherically hollow.

Concurrent, uniting, to the same Purpose.

Condense, to bring the Parts of Matter closer together.

Cone, a round Pyramid, or Spire.

Congeries, a Heap.

Connect, to knit together, or join.

Consistent, fixed, *i. e.* not fluid.

Consonant, correspondent to.

Contact, a touching each other.

Contiguous, Parts which touch.

Contort, twist; wind about.

Contorted, twisted round.

Convex, protuberant; swelling spherically outwards.

Convulsion, an involuntary Motion of the Muscles; a Twitching.

Corroborate, to strengthen or confirm.

Corrugation, a Contraction by wrinkling up.

Criterion, a Mark to judge by.

Cylinder, a solid Body, in Form of a Rolling-stone.

Cylindric, resembling this in Figure.

D

Density, Compactness; Closeness of Parts.

Deterfive, fit to cleanse or scower.

Diaphanous,

A GLOSSARY.

- Diaphanous*, transparent.
Diaphragm, the Midriff, dividing the Trunk of the Body into two Cavities, the *Thorax* and the *Abdomen*.
Diafole, the Dilatation of the Heart.
Digestion, the Conversion of the Aliments into Fluids.

E

- Ebullition*, a Bubbling, like boiling Water.
Efflux, the flowing forth of a Fluid.
Elastic, having a Spring.
Efferveſcence, a waxing hot.
Elasticity, endowed with the Property of a Spring.
Ellipſis, an oval Line or Surface.
Elliptical, oval, or like an Egg.
Excretory Ducts, very ſmall Canals for ſeparating the animal Juices.
Expanſe, Space extended.
Expiration, breathing forth.
Extravaſated, being out of the proper Veſſels.

F

- Fibre*, a ſmall String.
Fibril, one ſmaller ſtill.
Filament, a ſmall Thread.
Flaccid, lax, looſe or flabby.
Fluid, eaſily flowing or ſeparable.
Flux, the Act of flowing.
Foſſils, things ſolid, dug out of the Earth.
Fulcrum, a Prop or Point of Support.
Fulminate, take Fire as Lightning.
Fuliginous, ſooty, or reſembling Soot.
Frigoriſc, chill, or cauſing Cold.

G

- Gland*, a Bundle of connected Fibres to ſtrain the Fluids, and ſeparate finer Parts from them.
Gravity, Weight; the Tendency one Body has to another.
Groove, a ſmall Channel cut in a ſolid Body.
Gyration, a whirling round.

H

- Hemiſphere*, half a Globe.
Hermetically ſeal'd, Tube cloſed with melted Glaſs.
Hexangular, fix angled or ſided.
Horizon, the Limit of the Sight at Sea or on a Plane.

Hypo.

A GLOSSARY.

Hypothesis, a Supposition.

Hypothetical, suppositious.

Hydrostaticks, Doctrine and Laws of the grosser Fluids, as Water, &c.

Hydraulick, for the Purpose of raising Water.

I

Ignition, a taking Fire.

Immerse, to dip or plunge into.

Impel, to drive onwards.

Impinge, to strike upon, or against.

Incompressible, not to be reduced into less Compass.

Incidence, a falling, or lighting on.

Incumbent, lying upon.

Indefinite, undetermined, unlimited.

Ingenite, inborn, or produced with.

Insertion, a grafting in, or joining.

Inspiration, the drawing in the Breath.

Inspissate, to thicken or render viscid.

Intercostal, between the Ribs.

Interstice, Interval, or intermediate Space.

Inverse, when the Antecedents are turned into Consequents.

L

Lacteals, small Ducts in Animals, conveying a milky kind of Liquor.

Lambent, licking; unsteady.

Lateral, sidewise.

Libration, a balancing Motion.

Lobe, the Division of the Lungs and Liver.

Longitudinal, length-wise.

Lymphatic, conducting Lymph or watery Humours in the Body.

M

Meatus auditorius, the Passage into the Ear.

Medium, a Means of Conveyance.

Membrana Tympani, the Membrane covering the Drum of the Ear.

Microscope, Glasses for examining minute Bodies.

Miniature, contracted; drawn in little.

Moment, Force or Degree of Motion in any Body.

Monsoon, a Change, or Variation in the Direction of the Trade-winds settled between the Tropicks.

Morbid, sickly; diseased.

Mucus, slimy Matter.

Nadir,

A GLOSSARY.

N

Nadir, the Point just beneath us, on the opposite Part of the Globe.

Nerve, a Bundle of Fibres, arising from the Brain, whither it conveys Perception from every Part of the Body, and voluntary Motion back to particular Parts.

Nutrition, the Nourishment of an Animal.

O

Origin, Source, Rise or Beginning.

Ova, Eggs.

P

Percolated, strain'd thro' an incompact Body.

Percussion, striking, or the Effects of a Stroke.

Perennial, constant; the Year about.

Perforate to bore through, or pierce.

Pericardium, the Heart-bag.

Phænomenon, an Appearance in Nature.

Piston, a moveable Plug just fitting a Pipe.

Pleura, the Membrane lining the Chest.

Pneumatics, the Doctrine and Laws of the subtile Fluid the Air.

Polygon, a Figure containing more Angles than four.

Pores, small Passages in the Scarf-skin for the Sweat, &c.

Preponderate, to descend, being heavier.

Projectile, a Body in a Motion, cast or thrown.

Protrude, thrust away.

Protuberance, a swelling out.

Q

Quadratures, the quartering Points of an Orbit.

R

Rarefy, to thin, to lower, or weaken dense Matter.

Reflexion, a bending back, or returning a Body.

Reflex, reflected.

Reflux, the Return, or flowing back of a Fluid.

Reciprocal, mutual, or relative.

Refract, to bend or break.

Relaxed, less extended, loosened.

Reservoir, a Cistern or Head for a Reserve of Water.

Resilition, a Leaping back.

Reverberate, to beat back, or reflect.

Rigidity,

A G L O S S A R Y.

Rigidity, Inflexibility.

Rotation, a turning about ; like a Wheel on an Axle.

S

Salubrity, Wholesomeness.

Sanguification, the making Blood by Digestion, &c.

Secern, *Secrete*, to separate.

Similunar, like a Half-moon.

Sensorium, the Seat of Perception in the Brain.

Serosity, *Serum*, the wheyish Part of the Blood.

Similarity, a Likeness.

Species, Sort or Kind.

Spherule, a very small Sphere.

Specifick, peculiar, or appropriate.

Spicula, little Spikes.

Spiral, like a Rope coil'd round.

Spissitude, Thickness, Viscidity.

Sternum, the Breast-bone.

Stimulate, to provoke or incite.

Subterraneous, within the Earth.

Suction, the Faculty of Sucking.

Syphon, a bent Tube or Crane.

System, Composition, general Structure.

Systole, the Contraction of the Heart.

Synygies, the Opposition and Conjunction of a Planet with respect to the Sun and Earth.

T

Tangent, a streight Line, drawn from the Circumference of a Circle, touching it but in one Point.

Tautological, of the same Tenor or Sound.

Teguments, Coverings, as in the Body, Skin and Fat.

Tenacity, the clinging of the Parts of Fluids together.

Tendon, the Extremity of a Muscle.

Tensify, an Out-stretching.

Thorax, the Chest or Breast.

Transit, a passing of a Planet cross another in Course.

Transverse, cross wise.

Tropicks, imaginary parallel Lines to the Equator, at the Distance of $23^{\circ} 29'$ from it, being the Limits of the Declination of the Sun towards the North or South.

Tube, a Pipe.

Turbid, troubled, muddy, foul.

Turgid, swell'd.

Tympanum, the Drum of the Ear.

Vagut,

A GLOSSARY.

U

- Vague*, uncertain, wandering.
Valves, membranous Substances, acting like Trap-doors to prevent the Return of the Fluids.
Vapid, dead, tasteless.
Vena cava, the large Vein conveying the Blood back to the Heart.
Ventricle, a small Cavity.
Vermicular, Worm-like.
Vertebræ, the Chain of Bones, twenty-four in Number, reaching down the Back from the Head.
Vertex, the Top of any thing pointed.
Vibrate, to swing as a Pendulum ; to come and go as a Spring.
Viscid, *Viscous*, clammy, cohesive, as Bird-lime.
Undulating, a wavy Motion.
Volatile, subject to evaporate or fly away.

Z

- Zenith*, the Point above us in the Heavens ; or with respect to the Centre of a Sphere, any Point on the Surface.
Zone, a Portion of a Sphere surrounding it like a Gridle.



A N



A N

I N D E X;

Pointing out in what Page of this Treatise the following Particulars may be found.

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